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HIGHWAY RESEARCH REPORT

PLANTING TECHNIQUES AND MATERIALS FOR REVEGETATION OF CALIFORNIA ROADSIDES

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DECEMBER 1983

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16. Abstract

Plots of herbaceous and woody plant materials were established at six locations in the Mojave Desert. Grasses, legumes and shrubs were evaluated for survival, erosion control and esthetics. Woody plants were mainly native species. Plantings were also made on problem soils (serpentine soils, high boron soils, high and low pH soils) to determine suitable plants for use under adverse growing conditions. The rate of natural woody plant invasion onto cut and fill slopes was studied at over 100 sites in the Sierra Nevada Mountains, Sierra Nevada Foothills and Mojave Desert. Slopes of different ages were inventoried to determine the type of slope most receptive to plant invasion as well as the rate at which woody plants revegetate naturally. Plots established during the 1970-75 cooperative CALTRANS-SCS study were evaluated to note changes in plant performance that could influence current seeding and planting recommendations. A revised seeding guide is included.

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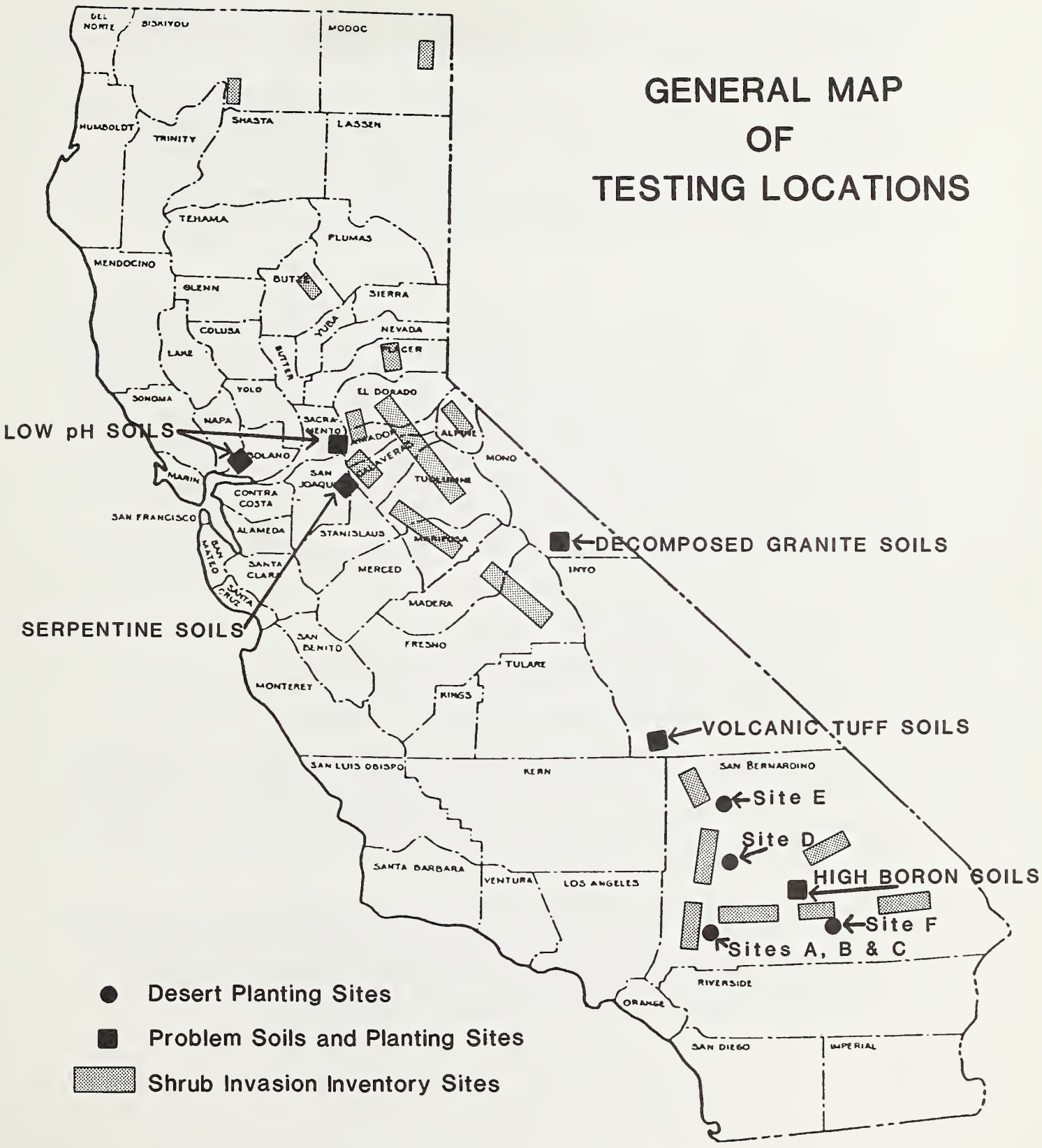
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This report has been reviewed by the California Department of Transportation and the Federal Highway Administration and approved for publication. The contents of the report do not necessarily reflect the views or policies of the State of California or the Federal Highway Administration. Any mention of products or trade names is for identification only and does not constitute an endorsement or recommendation.

The contents of this report reflect the views of the author who is responsible for the facts and accuracy of the data presented. The contents do not necessarily reflect the official views or policies of the STATE OF CALIFORNIA or the FEDERAL HIGHWAY ADMINISTRATION. This report does not constitute a standard, specification, or regulation.

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I INTRODUCTION

The U.S. Department of Agriculture, Soil Conservation Service (SCS) operates 23 Plant Materials Centers (PMCs) throughout the United States. These PMCs test and screen plants for use in conservation. The Lockeford, CA, Plant Materials Center (previously at Pleasanton) has been testing plants since 1939. In 1970 Caltrans signed an agreement with the SCS to test plants for use along California highways. This contract resulted in a report (titled "Plant Materials Study") which was published in 1976. Four geographical areas were emphasized: 1) the north-central coastal foothills; 2) the Sierra Nevada foothills; 3) the Tahoe Basin and vicinity; and 4) Alturas (in northeastern California).

In 1978 a second agreement was signed which provided for a study that concentrated on problems and geographic areas not stressed in the earlier project. This study was divided into four parts: 1) the establishment of herbaceous and shrub species in the Mojave Desert and adjacent areas; 2) a determination of the rate of invasion of woody plants onto disturbed sites; 3) the revegetation of problem soils (serpentine soils, high and low pH soils, and high boron content soils); and 4) a reevaluation of plantings made during the Caltrans-SCS cooperative study between 1970 and 1975. These areas of emphasis are discussed in Sections II, III, IV and V respectively.

Throughout the study reported here, attempts were made to use common methods of plant establishment. Variations were used only if they could improve the chances for plant survival. Practical and economical approaches to plant establishment were always prime considerations.

Some plants and seed were purchased, but most of the plant materials were collected by project personnel. The majority of the plant propagation was done at the Lockeford PMC. Early in the study some propagation was performed at the Antelope Valley Resource Conservation District Nursery near Lancaster, California.

All information and recommendations stemming from this study are a result of evaluations made by the author. No attempts were made to perform statistical analyses of the data.

This report is divided into six parts. The four primary areas of emphasis are discussed in separate sections. Some seeding recommendations appearing in the earlier plant materials study by George C. Edmunson, Jr., have been revised due to more recent plot evaluations and changes in plant availablity.

II REVEGETATION IN THE MOJAVE DESERT

Following highway construction, large areas are often left bare and in need of revegetation. In urban areas many of these sites can be irrigated which makes the selection of plant materials for erosion control relatively easy. Most excavated areas, however, are nonirrigated.

Climate conditions in the desert environment are severe and the number of plant species suitable for revegetation is limited. Desert areas left barren are extremely vulnerable to erosion by wind and water. Unsightly scars can persist for many years before any type of natural vegetation will appear. Information necessary for the successful revegetation of roadsides in the desert has often been inadequate. It is hoped that this study will add significantly to the current knowledge concerning revegetation in the desert environment.

Five planting sites were chosen that are representative of the conditions most likely to be encountered during highway construction. Differences in average annual precipitation were the basis for site selection. The testing locations were State Highway 14 at Avenues L and G (near Lancaster, CA); the Antelope Valley Resource Conservation District Nursery, 10 miles (16.1 km) west of Lancaster, CA; Edwards Air Force Base; U.S. 395 near Ridgecrest, CA; and the Lavic Road overpass at I-40, 40 miles (64.4 km) east of Barstow, CA. Average annual precipitation varied from 7.5 inches (19 cm) near Lancaster to 3.5 inches (8.9 cm) at the Lavic Road overpass.

SITE A - STATE HIGHWAY 14 AND AVENUE L

This planting site was chosen since it is a typical 'cloverleaf' arrangement often constructed near population centers. Irrigation water can be applied to these sites if they fall within the immediate boundaries of a city. However, freeways often run outside the city limits; in such areas dryland plantings must be made or the areas must be left to revegetate naturally.

Two plantings were made at this intersection in 1978, one in the northwest quadrant and one in the southeast quadrant. Direct seedings were made on the flat, and container plants were established on overpass fill slopes.

The soils are mapped as coarse, sandy loams but plantings are actually situated in subsoil. Average annual precipitation is 7.5 inches (19.1 cm) and the dominant surrounding vegetation is rubber rabbitbrush, big sagebrush, shadscale, desert saltbush, red brome, Arabian grass and cheatgrass.

Direct Seedings

Methods of establishment. Eighteen herbaceous species and 14 shrub species were direct seeded singly and in mixtures. As mentioned above, separate plantings were made in the NW quadrant and the SE quadrant to record any differences in plant performance due to exposure.

Herbaceous species were seeded in 5' x 100' (1.5 x 30.5 m) plots and shrub species in 5' x 80' (1.5 x 24.5 m) plots. The plots were laid out to have as many combinations of plant species as possible. Plots were furrowed to simulate drilling. The seedbed was disked and harrowed prior to seeding. Preparation such as this is practical where equipment has easy access to the planting site. Seed and fertilizer were broadcast into the furrows at a rate of 20 lbs/acre (21.8 kg/ha) and 250 lbs/acre (273 kg/ha) respectively.

At each of the two exposures, two blocks of the 18 herbaceous species and 14 shrub species were planted. One block was mulched with straw at a rate of 4,000 lbs/acre (4364 kg/ha) and the second was mulched with wood fiber at a rate of 2,000 lbs/acre (2182 kg/ha). The straw was stabilized by crimping with a colter.

Results and species adaptation. The annual grasses were able to respond quickly to available moisture. When there was sufficient precipitation for germination, 'Briggs' barley, 'Blando' brome, red brome, 'Wimmera 62' ryegrass and 'Zorro' annual fescue produced good stands. 'Briggs' barley did not perpetuate itself. There were scattered seedlings of 'Wimmera 62' ryegrass and 'Blando' brome in the second year but none in the third year. During the second growing season more red brome plants were observed growing within seeded plots than outside, but by the third year no differences were noted between the two areas.

1. Grasses and shrubs were seeded singly and in mixtures accompanied by both wood fiber and straw mulch (left). The annual grasses (right) produced rapid cover.

Patches of 'Zorro' annual fescue were still present in 1983. 'Zorro' had actually spread beyond the boundaries of the original plot. This species of annual fescue was not present in the vicinity before test plots were established; therefore, it is likely that the observed plants grew from seed originating from the test plots.

'Zorro' annual fescue and red brome are the most drought tolerant of the species tested. They will usually germinate with less precipitation than 'Blando' brome, 'Wimmera 62' ryegrass or 'Briggs' barley. With adequate precipitation 'Wimmera 62' ryegrass will produce abundant growth; however, this quality may not always be desirable since excessive growth can be a fire hazard.

2. 'Wimmera 62' ryegrass (center of plots) is a rapid developing, early growing annual grass. It has shown potential for erosion control in the desert environment.

A few seedlings of 'Berber' and 'Palestine' orchardgrass were observed. Generally, these two grass varieties will not survive in the intense heat of the desert environment. 'Largo' tall wheatgrass was the other perennial grass to survive through 1983. 'Largo' grew under both the wood fiber and straw mulches. 'Berber' and 'Palestine' responded only to the straw treatment. The perennial grasses were only present in the NW quadrant.

Of all the seeded species, 'Dorado' bladderpod and 'Marana' fourwing saltbush performed the best . Two older 1977 seedings of 'Dorado' and 'Marana' were growing well in 1983 but the 1978 seeding of 'Marana' was eliminated by inadvertent mechanical mowing. 'Dorado' seemed to be able to withstand mowing better than 'Marana'. Other shrub and grass species may also have been eliminated by mowing before their presence was noted.

Shrubs originating from seeded plots were only present in the NW quadrant. A heavy growth of mustard occupied both planting sites during the second year. This mustard took advantage of the fertilizer and severely competed with the planted species.

3. 'Dorado' bladderpod develops rapidly from seed. Seedlings (left) grew to 2-1/2 feet (0.75 m) (right) in height in two years.

Container Plantings

Methods of establishment. Container plants used during the 1978 planting were obtained primarily from commercial sources. Some species were raised at the Lockeford Plant Materials Center. Due to the late date of the study, sufficient time was not available to collect and propagate plant materials for the first year planting.

Container-grown plants were planted in holes approximately 12" (30.5 cm) deep. A bucket type post hole digger was used for gallon size stock. A 4-inch (10.2 cm) auger was used to prepare holes for plants raised in book binders (1-1/2 x 1-1/2 x 8" plastic containers, 3.8 x 3.8 x 20.3 cm). Two ounces (56.8 g) of Mag Amp fertilizer were mixed with the bottom backfill prior to planting. Soil was firmly packed around plants to remove air pockets. All plants were given one gallon (4 liters) of water at the time of planting to wet the backfill and to firm the soil around the roots.

Plantings were made between November 1, 1978 and April 1, 1979. The soil is moist and many plants are dormant at this time of the year. Plants established between these dates are able to acclimate themselves sufficiently to take advantage of early spring growing conditions.

Plants were planted ten per row and 3 feet (0.19 m) apart. This spacing is too small for use in a standard planting, but is adequate to observe plant performance. Each plant was irrigated with one gallon (4 liters) of water on June 1, July 1 and August 1, 1979. No irrigation water was applied after the first year.

Results and species adaptation. These plantings experienced heavy mortality early in the year. Soon after planting a cold spell set in, accompanied

by heavy snow. Many of the plants were small when planted; this resulted in a poor survival record. Unplanned mechanical mowing in late spring eliminated many of the plants that survived the severe winter. However, some plants that were beyond the reach of the mower could be evaluated for performance. Survival rates can be deceiving since factors other than natural factors caused some of the mortality. The results reported here are therefore based on subjective observations.

Container size did not seem to be a significant factor in survival. The species of plant and the quality of the seedling when planted were most important. Well developed indigenous plant species performed equally whether they were planted from gallon cans or book binders. The limited irrigation applied during the first year had little effect.

'Marana' fourwing saltbush and desert saltbush seemed to survive better on the south facing slope. The cold period that set in just after planting may have been tempered by this southern exposure.

Big sagebrush and rubber rabbitbrush were able to withstand mowing on both exposures. Plants were kept down to a mat form but did survive. California buckwheat has been seeded successfully by CALTRANS on many highway slopes in the Mojave Desert. Its poor showing in these container plantings must be attributed to the tender condition of the plant material at the time of planting. Only one plant survived the cold winter and mowing.

The costs to establish vegetation from containers is high. Establishment from seed is the preferred method. However, certain situations such as those at rest stops or busy intersections may warrant more intensive treatments. Container plantings of successful shrub species will usually result in a more rapid erosion control cover.

SITE B - STATE HIGHWAY 14 AND AVENUE G

A second planting site was located 3 miles (4.8 km) north of the one on Avenue L. Planting conditions were slightly different from those on Avenue L in that the site was further removed from the populated areas of Lancaster. Plantings were made in the NW and SE quadrants of this cloverleaf during both the fall of 1978 and spring of 1979. The soils are coarse, sandy loams. Average annual precipitation is 7.5 inches (19.1 cm). The dominant surrounding vegetation is rubber rabbitbrush, big sagebrush, shadscale, desert saltbush, Torrey saltbush, red brome, Arabian grass and cheatgrass.

Container Plantings

Methods of establishment. Only container plants were used at this location. The same planting procedures as discussed earlier were used here. Each plant was irrigated with one gallon (4 liters) of water on June 1, July 1, and August 1, 1979. No irrigation water was applied beyond the first year. All shrub accessions planted during the fall of 1978 on Avenue G were also planted on Avenue L. Several additional accessions were included in the spring planting.

Results and species adaptation. Early mortality was high among shrubs planted during the fall of 1978. Surviving shrubs were those native to the surrounding area. There is some indication that shrubs planted on the southern exposure were able to withstand the cold temperatures and snow better than those on the north facing slope. 'Marana' fourwing saltbush, desert saltbush and rubber rabbitbrush, all indigenous species, were the most successful shrubs planted.

It has been noted by others (2) that there is a greater possibility of losing shrubs if they are planted in the fall than if they are planted in late winter or early spring. There is the chance of a severe cold spell setting in during the period between December and March. Plants that are not sufficiently hardened off may quickly be killed by adverse climate conditions. Some of the losses experienced in the fall plantings on Avenues L and G were definitely a result of severe cold and mechanical breakage by snow and ice.

4. 'Marana' fourwing saltbush grew vigorously from containers on the fill material of the State Highway 14 and Avenue G overpass.

Early in the study plantings were made in the fall and winter (or early spring). As the project progressed, however, all plantings were made only in the winter or early spring. It was felt that when plantings were made in late March or April, plants still had adequate moisture to grow and become established before the onset of the hot, dry summer.

The 1979 spring planting on Avenue G had a high rate of survival. There were differences noted for the two exposures, but unfortunately some accessions were not planted on both. 'Marana' fourwing saltbush performed exceptionally well on the south exposure. A second accession of fourwing saltbush was the best of the eight shrub accessions planted on the north exposure.

Two sages not native to the immediate vicinity survived well on the south facing slope. Sand sage native to areas of the southwest outside of the Mojave Desert survived for more than one year. It is a low growing, attractive shrub but is not really suited for desert plantings. Silver sage grows commonly in the high desert above 6000 feet (1830 cm). It survived well but grew slowly. Nine of ten plants survived for more than one year but their growth was so slow that invading vegetatation soon overtopped them.

SITE C - ANTELOPE VALLEY RESOURCE CONSERVATION DISTRICT NURSERY

This nursery is located on Avenue I 10 miles (16 km) west of Lancaster, CA. An attempt was made to plant a representative number of each shrub accession planted at the four other sites in the Mojave Desert. Plant performance could be observed regularly by personnel stationed at the nursery.

Container Plantings

These plantings were made on class II agricultural land during the winters of 1980 and 1982. The site was not chosen to be representative of a typical roadside situation. Soils are mapped as sandy loams. Average annual precipitation is 7.5 inches (19.1 cm). Most of the surrounding land is abandoned cropland that has been invaded by Russian thistle, rubber rabbitbrush, red brome and cheatgrass.

5. Woody species growing at the Antelope Valley Resource Conservation District Nursery provided seed for propagation and direct seedings.

Methods of establishment. Standard planting procedures were used. The plants were given more intensive care than would be given shrubs planted along the highways. Observations of plant performance were made under good growing conditions.

During the first year following establishment, plants were irrigated monthly from May through October with one gallon (4 liters) of water each. Weeds around plants and between rows were hoed or mowed to reduce competition.

Results and species adaptation. Generally, plants performed well. Growth was rapid and first year survival was high. Taller indigenous species were showing vigorous growth in 1983. Oldman wormwood, silver sage, sand sage, Louisiana sage and fringed sage were all hurt by annual grass competition, rodent browsing and insects. Desert saltbush, 'Dorado' bladderpod, 'Marana' fourwing saltbush, 'Casa' quailbush and California buckwheat were the better performing shrubs.

SITE D - EDWARDS AIR FORCE BASE

In the fall of 1979, a site on Edwards Air Force Base (EAFB) was selected that was similar in most respects to a typical desert roadside. It was felt that plantings and evaluations could be made more conveniently there than along busy highways. The site is located on abandoned farmland where the soils are sandy loams. Average annual precipitation is 5.5 inches (13.98 cm) and the dominant surrounding vegetation is rubber rabbitbrush, cheatgrass and annual mustard.

Direct Seedings

Methods of establishment. Direct seedings made in 1978 on Highway 14 and Avenue L near Lancaster showed that straw mulch produced better results than wood fiber. Wood fiber was not used as the primary mulching material in any direct seedings trials after 1978.

Plots similar to those seeded in 1978 at the intersection of Highway 14 and Avenue L were established at EAFB. Eighteen herbaceous species and fourteen shrub species were seeded singly and in mixtures. The planting was situated on level ground and the seedbed was rototilled prior to treatment. All other planting procedures were the same as those used on Highway 14 and Avenue L in Lancaster.

Results and species adaptation. Four annual grasses, six perennial grasses and three shrubs produced stands by February 1980. 'Zorro' annual fescue was the first to germinate. 'Wimmera 62' ryegrass, 'Blando' brome and red brome followed soon after. There were only scattered plants of seeded perennial grasses. The seeded species that germinated are listed below.

Annual Grasses	Perennial Grasses	Shrubs
'Zorro' annual fescue	'Barton' western wheatgrass	Big sagebrush LK-1306
'Blando' brome	'Arriba' western wheatgrass	'Dorado' bladderpod
'Wimmera 62' ryegrass	Western wheatgrass LK-1296	Desert saltbush LK-1069
Red brome PL-103-71	Western wheatgrass LK-1298	
	Siberian wheatgrass LK-1295	
	'Largo' tall wheatgrass	

Big sagebrush germinated rapidly and averaged 1-3 inches (2.5-7.6 cm) in height by April 1980. 'Dorado' bladderpod reached 2-3 inches and desert saltbush 1-2 inches (2.5 x 5 cm) in height by the same date. All three species exhibited vigorous early growth. By August 1, however, all grass and shrub seedlings were gone. Heavy rodent browsing eliminated the planting. No further germination was observed in any of the plots. A heavy growth of mustard occupied the site in subsequent years.

Container Plantings

Methods of establishment. Over 500 shrubs were planted at EAFB in November 1979. The same planting techniques were used as previously described. A motorized two-man posthole digger was needed to prepare holes for planting. Some desert soils when dry are extremely hard and difficult to work. Often, when dry conditions are encountered, it is necessary to prepare shallow basins, apply water and allow the water to percolate before attempting to dig holes and plant shrubs. Usually six to eight hours are required for water to percolate to sufficient depth. A chicken wire fence was strung around the periphery of the 1979 shrub block as protection against rabbits and other rodents.

Due to unexpected mortality, a second shrub planting was made in this same location during February 1980. The odd-numbered plants of each shrub accession were irrigated with one gallon (4 liters) of water on June 1, July 1 and September 1, 1980. Instead of fencing, a commercially produced rodent protector was placed around each individual shrub. These devices were 3" x 15" (7.6 x 38.1 cm) cylinders made of perforated plastic. Protectors were fabricated so as to break down after three to five years of sunlight.

Results and species adaptation. By January 1980 all but seven plants of the November 1979 planting were gone. Only two fourwing saltbush, one shadscale and four bladdersenna remained. Wind had blown Russian thistle and other plant residue against the protective fence, allowing rodents to enter. Browsing soon eliminated all but the above-mentioned shrubs. Most desert container plantings from this time on were protected by rodent protectors.

6. It is difficult to establish container plants without some type of protection from wildlife. Five hundred shrubs were destroyed by rodents within one month of planting at the Edwards Air Force Base site.

The second planting made at this site contained 280 shrubs representing 25 accessions. As a result of rodents burrowing under or gnawing through protectors, motality was high in this planting. However, the protective devices did allow evaluation of some plant accessions.

Two shrub species survived through the last evaluation date in March, 1983. Big sagebrush and desert saltbush looked good. No differences could be seen between irrigated and nonirrigated plants. Big sagebrush mortality could not be attributed to any single factor. Plants were well developed, had survived periods of drought, and showed no apparent rodent damage, but were dead. Mortality occurred after two years, whereas most of the losses within the desert saltbush accessions took place during the first year following establishment.

Several other species from the 1980 planting survived for two years but lacked the vigor necessary for an effective erosion control plant. No plants from the 1979 planting survived beyond two years. The most palatable species were eventually eliminated through browsing. Protective devices were broken by wind-driven debris or damaged sufficiently by wildlife to allow ready access. Plantings situated closer to busy highways did not experience the severe wildlife damage that this planting on EAFB received. Several other plant species such as fourwing saltbush, rubber rabbitbrush, and shadscale would probably have been successful on this site if it were not for constant pressure exerted by wildlife.

7. Most shrubs at the time of planting (left) are very palatable and must be enclosed within some type of device (right) for protection against rodents.

SITE E - RIDGECREST (U.S. 395)

This site is located 11 miles (17.7 km) west of the city of Ridgecrest, CA along U.S. 395. The slope is a west facing cut slope representative of the soils and climatic conditions of the northwest Mojave Desert. Even though more than 20 years old, many of these slopes are still in need of revegetation.

Direct seedings were made during the fall of 1978, 1979, 1980, and 1981. Container plantings were made in the fall of 1979 and during the spring of 1980, 1981 and 1982. The soil can best be described as a cobbly, sandy loam. Much of the soil material is parent material covered by wind-blown or washed sandy loam. Average annual precipitation is 5 inches (12.7 cm). The surrounding vegetation is primarily desert saltbush, bursage, creosote bush, armed senna, rubber rabbitbrush, cheatgrass and Arabian grass.

Direct Seedings

Methods of establishment. Since many of the herbaceous and woody species did not germinate or only produced sparse stands, it was felt that little information could be gained by seeding mixtures. Therefore, most direct seedings after 1979 were established in single species plots.

In 1978, plots were broadcast-seeded at a rate of 40 lbs/acre (43.6 kg/ha) and fertilized with 16-20-0 fertilizer at a rate of 250 lbs/acre (273 kg/ha). Only a wood fiber mulch at a rate of 4,000 lbs/acre (4364 kg/ha) covered the seed. In 1979 seed was drilled (simulated drilling by furrowing and hand seeding into furrows) at a rate of 20 lbs/acre (21.8 kg/ha), fertilized as above and mulched with a 4,000 lbs/acre (4364 kg/ha) rate of straw. The straw was covered with wood fiber at a rate of 750 lbs/acre (818 kg/ha) to act as a binder. In 1980 the same procedure was used as in 1979 except that a paper product was substituted for the wood fiber to act as a straw binder. The paper product was also applied at the 750 lbs/acre (818 kg/ha) rate. Plots from 1978 through 1980 were all 10' x 20' (3.0 x 6.1 m).

8. Straw has been the best mulch material. A paper slurry or wood fiber mulch sprayed over straw is an effective tackifying agent.

In 1981, one plot of an herbaceous mixture was seeded. The seed was hand-seeded into furrows and covered. The same seeding and fertilizer (16-20-0) rates were used as in 1980 but no mulch was applied. Also in 1981 there

were 76 shrub accessions and two perennial grass species seeded into 5-foot long (1.5 m) furrows. A 20 lbs/acre (21.8 kg/ha) seeding rate and a 250 lbs/acre (273 kg/ha) fertilizer rate were again used. Furrows were raked after seeding but no mulch was applied. Several mulch trials were run in 1981; these will be discussed in a later section.

Results and species adaptation. Only seven herbaceous species germinated. No germination was observed from the 1978 seeding. 'Zorro' annual fescue, 'Blando' brome, red brome and 'Wimmera 62' ryegrass were the only grasses emerging in 1979 and 1980. Four annuals (a mixture of 'Zorro', 'Blando', common rose clover and red brome) and two perennials ('Luna' and 'Largo' seeded in separate furrows) seeded in 1981 all emerged. The 1979 plot of red brome reseeded adequately to produce a good stand in 1980. 'Blando', 'Zorro' and 'Wimmera 62' also reseeded but only scattered seedlings were observed in 1980. After two years only traces of these four species were found in the 1979 plots. A few plants of 'Zorro', 'Blando', red brome and 'Wimmera 62' ryegrass from the 1980 seeding developed and set seed but stands did not persist.

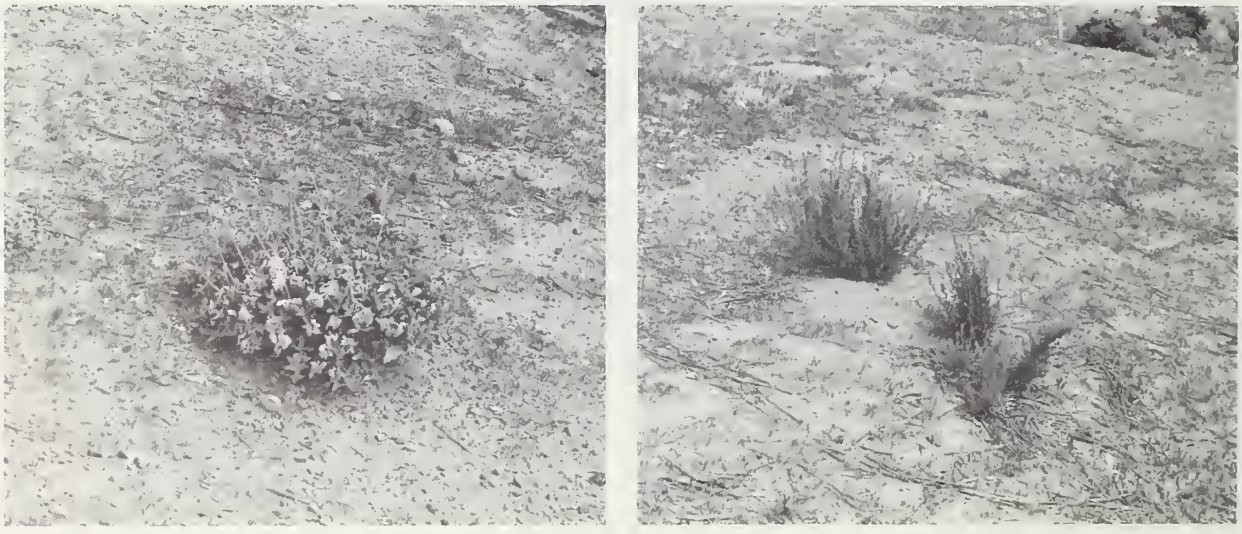
The plot of mixed annuals seeded in 1981 ('Zorro', 'Blando', red brome and common rose clover) produced a ground cover of about 50%. However, only scattered plants were present in 1982. If 'Hykon' rose clover, an early maturing strain, had been used rather than the common variety, reseeding might have taken place. However, 'Hykon' seed was not available at that time. Soil moisture was exhausted long before common rose clover could produce mature seed.

The two perennial grasses seeded in 1981, 'Largo' and 'Luna', emerged and grew to a height of about 4 inches (10.2 cm). However, by September 1 both species were dead. These are two of the best perennial grasses for use on the deep fill material within the Mediterranean-type climates, but, they are not able to survive the shallow soils of cut slopes and extreme climatic conditions present in the desert environment.

Each year from 1978 through 1982 Arabian grass, a nonnative indigenous annual, produced a semi-dense cover where fertilizer had been applied. This short opportunistic grass species responds rapidly to fertilizer and precipitation. Since it is common throughout much of the Mojave Desert, disturbed sites can often be vegetated temporarily by encouraging its development with fertilization.

9. Desert saltbush (left) and 'Marana' fourwing saltbush (right) are two of the most promising woody species growing from seed in the Mojave Desert.

Seven woody species grew from direct seedings. Seedings made in 1978 did not emerge. Desert encelia, 'Dorado' bladderpod, 'Marana' fourwing saltbush, California buckwheat, quailbush, and desert saltbush all germinated in 1979 and were alive at the time of the last evaluation in March 1983. Desert encelia and desert saltbush planted in 1980 emerged and were also alive in March 1983.



10. Desert encelia (left) and California buckwheat (right) add color to roadside plantings. Both species grew from seed.

Of the 76 woody accessions seeded in the fall of 1981, one accession of winterfat and three accessions of bladderpod germinated. Winterfat was gone by July 1, 1982, probably as a result of rabbit browsing. Plants reached a height of about 2 inches (5 cm). All three accessions of bladderpod were alive in March 1982.

Desert saltbush was definitely the superior shrub species seeded at this site. Numerous plants germinated from both the 1979 and 1980 seedings. Sufficient ground cover was formed to effectively check erosion. Initial coverage was about 60%. Plants showed signs of rodent damage but were able to withstand browsing pressure well. Only a few plants of other successful shrubs developed into mature plants. 'Marana' fourwing saltbush was kept small by browsing but did remain vigorous. Quailbush attained a height of about 5 feet and a width of 4 feet (1.54 x 1.22 m). Desert encelia and California buckwheat both grew to about 10 inches in height and 12 inches in width (0.25 x 0.03 m). All four accessions of bladderpod, including 'Dorado', were stunted. Bladderpod is more suited to the well drained soils of the desert uplands.

Herbaceous species can best be used in the desert as short term cover. Long term erosion control can best be achieved by seeding woody plants. Table II-1 (at the end of this section) shows a proposed seed mixture. Species in this mixture are those that showed the most promise in seedings at this site.

Container Plantings

Methods of establishment. Between 1979 and 1982, 476 container plants were established at the Ridgecrest location. Standard planting techniques were used throughout. Rodent protectors were not used in the fall 1979 planting and all but three desert saltbush plants were destroyed. Subsequently, all plants were enclosed within protective devices.

Plants were watered with one gallon (4 liters) of water each at the time of planting. Irrigation trials were organized so that several plants of each accession were watered monthly from April through October. Basins were constructed around each irrigated plant and then one gallon (4 liters) of water was applied from a bucket. The irrigation schedule was followed from the time of planting through the end of the project.

Originally from eight to ten plants of each accession were planted. As accessions increased in numbers, plants were reduced to five per accession. If more than five plants were planted, the even numbers were irrigated. If exactly five were planted, the odd numbers were watered. Where three or less were established all were irrigated, and when only four were available the second and fourth were irrigated.

Results and species adaptation. Container plants of grasses were planted to see whether seedling grasses would become established more readily than grasses in direct seedings. If container grasses could be established, plants would act as seed sources. Rhizomatous grasses are preferred since they spread vegetatively as well as by seed.

The survival of most grass species was fair to good, but growth was so poor that it appears that planting container grasses under these conditions is impractical. Irrigation may have increased survival of 'Berber' and 'Palestine' orchardgrass; however, these varieties are best adapted to warmer climatic conditions. No height or width measurements were recorded for the grasses due to their poor performance.

11. Container plantings can be expensive. However, more rapid shrub establishment can often be achieved by planting container stock rather than seeding.

Container type had little effect on plant performance. A well developed and hardy plant raised in a book binder had about the same chance for survival as one raised in a gallon can. The species of plant used was more important than the treatment employed.

12. Desert saltbush (left) grew well in container plantings. 'Casa' quailbush is less cold-tolerant than other saltbushes but it produced vigorous rapid growth at Ridgecrest.

Irrigation may have aided the survival of some species. Desert peach, big sage, rabbitbrush, spiny hopsage and wolfberry did perform somewhat better under irrigation. Since plant numbers included in the comparison were small, results had to be interpreted subjectively. Plant species indigenous to the planting location generally showed no effects from irrigation.

13. Oldman saltbush (left) was the only nonnative species to show promise in container plantings. California buckwheat (right) developed faster from container stock than from seed.

The most outstanding shrub at this site was desert saltbush. It was the only species to survive from the 1979 fall planting. Its survival and growth were exceptionally good in each of three subsequent plantings. Other species showing good growth and vigor were: 'Marana' fourwing saltbush, shadscale, 'Casa' quailbush, California buckwheat, white bursage, Oldman saltbush, big sagebrush and desert broom. Survival of creosote bush was good but growth was slow. Rubber rabbitbrush grew rapidly but survival was not as good as expected from such an invasive species. Nevada epheda and green epheda showed a high rate of survival but growth was also very slow.

14. Shadscale (left) and creosote bush (right) are not easily grown from seed but survival among established plants was high.

SITE F - LAVIC ROAD OVERPASS

The Lavic Road overpass site was located 40 miles (64.4 km) east of Barstow, CA on I-40. Plantings were made on a north facing slope. This portion of I-40 was built in the mid-1960's but still lacked adequate cover in 1979 when plantings began.

Direct seedings were made during the fall of 1979, 1980 and 1981. Container plantings were made in the fall of 1979 and the late winter of 1981 and 1982. The soils are gravelly, cobbly sands of relatively low water-holding capacity. This location receives the lowest amount of precipitation of any site planted during the study. Average annual precipitation is 4 inches (10 cm). The primary surrounding vegetation is creosote bush, white burrowbrush, white bursage, desert saltbush and desert holly.

Direct Seedings

Methods of establishment. In 1979 and 1980, seedings were made in a manner similar to those at Ridgecrest. Plots were 10 x 20' (3.0 x 6.1 m) in size, seeding rate 20 lbs/acre (21.8 kg/ha), fertilizer rate (16-20-0) 250 lbs/acre (273 kg/ha) and straw mulch rate 4,000 lbs/acre (4364 kg/ha). Because of the gentle slope at Lavic Road, the straw was punched in with a colter. Seed and fertilizer were broadcast by hand and then straw was blown on with a commercially manufactured straw blower.

15. Straw applied to shallow soil and crimped will blow more easily than if bound with a tackifying agent. Wind at the Lavic Road site quickly dislodged straw.

In the fall of 1981, 47 accessions of shrubs were seeded into individual 5-foot-long (1.5 m) rows. Fertilizer (16-20-0) at a 250 lbs/acre (273 kg/ha) rate was applied with the seed and then the furrows were covered. No mulch was applied in 1981.

Results and species adaptation. The year 1980 was an above-average rainfall year. Both the Barstow and Daggett weather stations recorded above-average precipitation. Thirteen of the species planted in 1979 germinated. Three perennial grasses, 'Largo', 'Luna' and 'Lehmanns' lovegrass, germinated but did not tolerate the heat and drought of the summer months. Five annual species, 'Blando' brome, 'Wimmera 62' ryegrass, 'Zorro' annual fescue, red brome and Indian wheat, germinated and set seed but no plants were observed after the first year. Five shrub species (big sagebrush, desert encelia, 'Casa' quailbush, 'Marana' fourwing saltbush and desert saltbush) germinated. The latter three species were alive in March 1983.

16. 'Casa' quailbush grew from seed during above normal rainfall years.

The accessions planted in 1979 were again seeded in 1980. No germination was observed. Both the Barstow and the Daggett weather stations indicated below-average precipitation for 1981.

Within the 1981 block of 47 seeded accessions a few winterfat plants were observed in March 1982. All were gone by April 1982. During years of normal precipitation, germination of annual grasses and indigenous shrubs will usually occur.

Often, precipitation in the desert occurs in heavy local downpours. If herbaceous species such as 'Zorro' or red brome were to germinate and establish stands before such storms occur, much soil erosion could be checked. Herbaceous annuals will usually provide a quick cover. Woody species can provide better long term covers.

Container Plantings

Methods of establishment. Because of the hardness of the soil material, holes for container plants were dug with a shovel and pick rather than a conventional auger. Basins were prewatered before digging.

During the fall of 1979, 70 shrubs were planted. Plants were established on 3-foot (0.91 m) centers and watered at planting time. Three of the five plants were irrigated with one gallon (4 liters) of water in April, June and July 1981. No rodent protectors were used in the 1979 planting.

In late winter, 1981, 100 shrubs and 45 grasses were planted from containers. Plans were made to water plants from April through October but actual irrigation did not begin until June 1981. Rodent protectors were used.

The 1982 planting contained 120 plants representing 23 shrub accessions. There were five plants of all accessions except creosote bush, which had ten. Irrigation trials were carried out from April through October using procedures previously described. Shrubs in this planting were also enclosed within rodent protectors.

Results and species adaptation. Several nonindigenous shrub species planted in 1979 died soon after planting. 1980 was an above-average rainfall year, but precipitation was not sufficient to sustain sand sage, fringed sage, prairie sage, big sage and silver sage. All of these plants died even before the onset of the hot weather. Supplemental irrigation had no effect on survival.

Rodent depredation on planted species tends to be less during years of good rainfall. The availability of natural feed during good years made the planted species less subject to wildlife damage. 1980 was above-average in precipitation and planted shrubs were not harmed. 1981 was a below-normal rainfall year.

All saltbushes, rabbitbrush, and soap tree plants survived into the second year; however, as natural feed became exhausted, those species that did not attain sufficient height to withstand browsing were severely eaten back. Soap tree survived because it was either unpalatable or too small to be found. Two accessions of fourwing saltbush and one accession of desert saltbush also survived. No significant differences were seen between irrigated and nonirrigated plants.

17. Desert saltbush and 'Marana' fourwing saltbush were the most promising shrubs planted from containers at the Lavic Road site.

Few plants survived from the 1981 planting. Irrigation was not accomplished until June 1981. By that date most plants had already died. All remaining plants were irrigated in June. Little rain was received on the site in 1981. One plant of big sage and two plants of desert saltbush survived until the last evaluation in March 1983.

The 1982 planting contained a greater variety of woody species than either of the two previous plantings. Twenty-three species were included. Irrigations were made as planned, but no significant differences were observed between irrigated and nonirrigated plants. The superior species within this planting were 'Marana' fourwing saltbush, Torrey saltbush and creosote bush. Several other species survived until the summer of 1982 but did not perform well enough to be recommended for desert roadside plantings. Table II-2 lists those woody species most likely to be successful from containers.

Table II-1. Recommended shrub species and seeding rates for use on road slopes in the northwest Mojave Desert

Species	Seeding Rate (pounds/acre)*
5-8" (13-20 cm) Precipitation	
'Marana' fourwing saltbush	10
Desert saltbush	15
'Casa' quailbush	5
'Dorado' bladderpod	15
Big sagebrush	5
Desert encelia	5
	55
3.5-5" (8.4-13) Precipitation	
'Marana' fourwing saltbush	10
Desert saltbush	15
'Casa' quailbush	5
'Dorado' bladderpod	10
	40

*To convert to kg/ha, multiply by 1.091.

Table II-2. Recommended container plants for use in the Mojave Desert and vicinity

5-8"+ (13-20 cm) Precipitation	3.5-5" (8.4-13 cm) Precipitation
'Marana' fourwing saltbush	'Marana' fourwing saltbush
'Casa' quailbush	Shadscale
Shadscale	Desert saltbush
Big sagebrush	Creosote bush
Desert saltbush	Bursage
California buckwheat	Bladderpod
Rabbitbush	
Bursage	
Green ephedra	
Desert broom	
Creosote bush	
Bladderpod	
Oldman saltbush	

*All container shrubs must be protected against rodents with some type of enclosure.

EVALUATION OF SAND PANICUM FOR EROSION CONTROL IN THE MOJAVE DESERT

This study was made to investigate ways to establish sand panicum along California highways. Sand panicum, Panicum urvilleanum, is a drought-tolerant, sand-binding, native perennial grass that has potential for soil stabilization in the desert environment. This species seems to grow best on frequently shifting sandy soils. The grass is a low seed producer but it has been observed to spread when suitable conditions exist. It is possible that wind-blown soil is a continual source of nutrition and this grass occupies sandy sites in order to take advantage of the higher fertility levels made available by the wind-blown material.

18. Sand panicum plots were established under the same types of conditions (left) that support natural stands (right).

Methods of Establishment

A row of sand panicum had been established at the Antelope Valley Resource Conservation District Nursery near Lancaster as part of an earlier study. This row was used as the source of material for plantings established during the winter of 1980. Plant clones were transplanted from the nursery row to these outlying sites. Clusters of four or five clones each were planted on 1.5 foot (0.45 m) centers. Twenty-five clusters, planted as a square, comprised a plot. Ammonium phosphate sulphate fertilizer (16-20-0) at a rate of 500 lbs/acre (546 kg/ha) and straw mulch at a rate of 6,000 lbs/acre (6546 kg/ha) were applied at the time of planting. The straw was tucked in with a spade.

One plot was on the south bank of Cache Creek, 3 miles (4.8 km) north of the town of Mojave on Highway 14. The second plot was established in sandy soil at the intersection of Basin Road and I-15 west of Baker.

Results and Discussion

Plants were dormant when established. The soil was moist at the time of planting and rain fell several times during the next few months. Unfortunately, the sand panicum never showed any sign of growth. Wheat straw was used for mulch and seed from the straw germinated, taking advantage of the fertilizer. Abundant early growth of wheat probably exhausted available nutrients and moisture before the sand panicum had an opportunity to start growth. Sand panicum is a warm season grass and most of its growth occurs in late spring and early fall. Another possible reason for the failure of the trial could be that dormant sand panicum clones were planted with old growth still attached. The dry, dead foliage may have acted as a wick, drawing moisture from the plant material before it became active in the spring.

These were the only two plantings of sand panicum made as part of this project. This grass species possesses qualities wanted in an erosion control plant, and further testing is definitely warranted. For best results, old growth should be removed from dormant plants before establishment and straw should not be used as mulch.

THE EFFECTS OF MULCH ON PLANT ESTABLISHMENT

Several mulch trials were run in association with seedings near Lancaster (Avenue L and Highway 14), Ridgecrest, Little Lake and San Andreas (State Highway 49). The San Andreas site is not within the desert environment. However, the discussion is included here for comparative purposes. Burgess L. Kay (4) has done extensive work with mulches, so it was decided to incorporate several of his recommendations into the study. Three mulches (Astromulch, Silva-fiber and straw) were tried in single applications and as combinations of several products.

Trial Methods

In the 1978 direct seeding trials on Avenue L and Highway 14 near Lancaster, two plots of each plant accession were seeded. One plot was mulched with Silva-fiber (a wood fiber product) at a rate of 2,000 lbs/acre (2182 kg/ha) and the second plot was straw mulched at a rate of 4,000 lbs/acre (4364 kg/ha). A 250 lbs/acre (273 kg/ha) rate of 16-20-0 fertilizer was applied to both plots.

Ferilizer was included as part of the slurry in the wood fiber mulch plot but it had to be put on by hand prior to the application of straw. A straw crimper was used to tuck the straw into the soil.

In 1979, three mulch trials were run at the Ridgecrest site. In the first trial, single species plots were seeded, fertilized and straw mulched at the standard rates--20 lbs/acre seed (22 kg/ha), 250 lbs/acre fertilizer (273 kg/ha) and 4,000 lbs/acre (4364 kg/ha) straw. However, Silva-fiber at a rate of 750 lbs/acre (818 kg/ha) was applied over the straw to act as a binder.

19. A paper residue mulch and a wood fiber mulch were compared to observe plant performance and mulch longevity. Wood fiber was applied to the top of the slope and the paper mulch to the bottom.

The second trial consisted of two replications of nine species each. Plots were hand seeded and fertilized at the standard rates. One replication was mulched with Silva-fiber and the second with Astromulch (a paper product). Both mulches were applied at a rate of 2,000 lbs/acre (2182 kg/ha).

The third trial also compared Silva-fiber and Astromulch in separate replications but 'Zorro' annual fescue and red brome, along with the 16-20-0 fertilizer were applied within the mulch slurries. The seed mixtures were applied at a rate of 35 lbs/acre (38 kg/ha).

During the fall of 1979, plots at Little Lake were straw mulched in a manner similar to those at Ridgecrest. However, Astromulch (at the same rate as wood fiber) was used as the straw binder.

Several Astromulch treatments were made on a serpentine soil near San Andreas during the fall of 1979. A more detailed discussion of this trial appears elsewhere in this report. Two mulch rates and two seeding methods were compared. In one replication, ten single plots of grasses and shrubs were seeded and covered with 2,000 lbs/acre (2182 kg/ha) of Astromulch. In a second replication, the same species were seeded as part of the astromulch slurry but the mulch rate was increased to 4,000 lbs/acre (4364 kg/ha). Two unseeded plots were also mulched, one with the standard 2,000 lbs/acre (2182 kg/ha) rate and the second with a double rate. Fertilizer (16-20-0) rates for all plots were 400 lbs/acre (436 kg/ha).

Results and Discussion

Even though germination was low for most species seeded on Avenue L and Highway 14, those that grew showed more vigor and height growth in the straw plot than in the plot mulched with wood fiber. This observation

confirms the recommendations made by others (4), and was the basis for using straw as the primary mulch material in subsequent plantings. The only drawback with straw is that weed and grain seed is often applied with the straw. The grasses and weeds germinating from seed within the straw can compete severely with planted species. If other straw mulches were used, such as those from rice or perennial grasses, introduced weeds could be kept to a minimum. These materials, however, are not always available.

At Ridgecrest, a number of species grew well within the straw plots covered with wood fiber. In areas of higher precipitation wood fiber will hold straw adequately until grasses germinate and grow. However, under desert conditions grass growth is dependent upon unpredictable rainfall and straw may remain for long periods before germination occurs. It was not really known how long the wood fiber would hold the straw on the slope.

Results showed that straw moved little even though subjected to heavy winds. After six months, most straw was still in place. Adequate mulch was present to protect emerging plants. The only straw movement occurred where water had concentrated and forced both soil and straw from the plot.

No differences in plant performance were observed between plots mulched with wood fiber and those mulched with Astromulch. However, the two mulches differed in their resistance to decay. Little wood fiber was present after 18 months but a high percentage of the paper product still persisted. Mulches themselves supply a certain amount of erosion control. The paper product provided slope protection longer than wood fiber. Volunteer stands of Arabian grass were denser within the wood fiber plots. This may be attributed to mulch thickness since the Astromulch was too thick in some portions on the plots. Grass seedlings may not have been able to push through the thick layer.

No differences in plant performance could be attributed to the mulch treatments on the serpentine soils north of San Andreas. First-year response in all plots was good. Volunteer grass growth in a fertilized nonmulched plot was similar to that within the seeded test plots. Differences observed in subsequent years were caused by factors other than mulch rates.

20. Paper mulch was present 18 months after application whereas most wood fiber was gone.

Straw is the recommended mulch material whenever it can be applied. At some sites, however, it is too difficult to apply straw, so wood fiber or a paper product must be used. If either of the latter two mulches is used, a rate of at least 2,000 lbs/acre (2182 kg/ha) should be applied. Some sites that normally require hydromulching can probably be straw mulched with the aid of wood fiber or a paper product as a binder.

CONCLUSIONS AND GENERAL RECOMMENDATIONS

Direct Seedings for Erosion Control

No perennial grass performed well enough to recommend its use in a seeding mixture for the Mojave Desert. Several perennial grasses germinated, such as 'Luna' pubescent wheatgrass and 'Largo' tall wheatgrass, but none could tolerate the droughty soils and intense heat of the desert environment.

Annual grass and legume species are the best herbaceous plants to seed. They are opportunistic and take advantage of moisture when it is available. Red brome, which is sometimes available commercially, was the best annual grass planted. It perpetuated itself for several years. 'Zorro' annual fescue produced good stands at several locations but only persisted at the Lancaster site. 'Blando' brome and 'Wimmera' '62 ryegrass produced stands only during the year of planting. A commercial strain of rose clover germinated but did not set seed. An early maturing strain such as 'Hykon' would probably be more successful.

Arabian grass, an indigenous annual, grew and produced cover wherever fertilizer had been applied. It is a low growing, fine textured, cool season grass that germinates naturally with the first rains. Occasionally this species is commercially available and could be included in a seeding mixture for use in areas where there is not yet a dense natural seed source.

The most successful seeded species were woody plants. Desert saltbush, 'Marana' fourwing saltbush, 'Casa' quailbush, California buckwheat, big sagebrush, and desert encelia were the best shrub species seeded. Bladderpod germinated but its use should be limited to the gravelly and well drained desert uplands.

Big sagebrush is a member of the sunflower family and its seed will generally remain viable for only one year. If sufficient precipitation does not occur during the year of seeding, this species must be reseeded if it is to be part of the shrub composition. Seed of the other shrubs mentioned above will normally remain viable for several years.

Direct seedings should be drilled wherever possible. Seeds broadcast onto the soil surface and covered with mulch have less chance of germinating than seeds incorporated into the soil. Fertilizer, such as ammonium phosphate sulphate 16-20-0, at a rate of 250 lbs/acre (273 kg/ha) should accompany the seed.

Straw is the preferred mulch material. It should be applied at a rate of 2 tons/acre (1.96 metric tons/ha). Wood fiber and paper mulch products have not been as successful as straw. Wind will readily blow straw if it is not

secured to the slope. A 750 lbs/acre (818 kg/ha) rate of wood fiber or a paper mulch product sprayed over the straw is an effective tackifier. Seeding and mulching should be done in early or mid-fall.

Container Plantings for General Revegetation and Erosion Control

The best container plants tested in the Mojave Desert were: desert saltbush, 'Marana' fourwing saltbush, 'Casa' quailbush, California buckwheat, rubber rabbitbrush, creosote bush, big sagebrush, shadscale, desert broom and oldman saltbush. The type of plant container did not seem to influence survival. The vigor and condition of the plant at the time of establishment were most important.

All container plants were subject to rodent damage. Plants were browsed least during years of good precipitation when natural wildlife food was abundant. As a precautionary measure, rodent protectors should be included as a part of all plantings.

Irrigation did not increase the survival of most shrub species. Irrigation may be helpful if precipitation during the establishment year is abnormally low. The best shrubs are naturally adapted to the drought and intense heat of the desert environment.

Both fall and late winter plantings were made. However, there is always the possibility of a severe winter cold period between November and March, so late winter or early spring plantings are recommended. Plantings made during this latter period still give plants sufficient time to acclimate themselves before the onset of the summer months.

III NATURAL INVASION OF WOODY PLANTS ONTO HIGHWAY SLOPES

Highway construction in hilly and mountainous terrain results in deep cut and fill areas that need vegetation for erosion control and aesthetics. A common practice is to seed herbaceous plant materials, apply fertilizer and cover plantings with a straw or wood fiber mulch. The herbaceous plant cover can reduce the unsightliness of exposed parent materials and can check erosion. Usually, only areas around population centers are planted with adapted shrubs and trees. Other areas are left to revegetate naturally.

21. Some road slopes are bare for many years before any natural woody vegetation develops.

This study discusses several factors which are important in the natural invasion and revegetation process. One of the primary purposes of the study was to determine some of the conditions that enhance natural woody plant invasion onto highway cut and fill slopes. If conditions favorable to plant invasion can be duplicated, it may not always be necessary to revegetate after construction.

The geographic areas studied were: 1) Sierra Nevada Mountains; 2) the Sierra Nevada Foothills; and 3) the Mojave Desert. The Sierra Nevada Mountains were further subdivided into the Sierra Nevada Mountains (East) and the Sierra Nevada Mountains (West); the dividing point was the crest of the mountains. Sample locations are listed in Appendix D, Table 9.

METHODS AND PROCEDURES

Twenty-four variables at each sample site were scheduled for sampling. These were designated by exposure, type of slope, age of slope, and amount of herbaceous cover as shown in Table III-1. In no area were all 24 variables available.

Table III-1. Diagnostic representation of 24 sample variables

Exposure	Type of Slope (cut or fill)	Age of Slope: 0-2 Years Herb	0-2 Years No Herb*	3-6 Years Herb	3-6 Years No Herb	Over 6 Years Herb	Over 6 Years No Herb
N	Cut	1**	2	3	4	5	6
N	Fill	7	8	9	10	11	12
S	Cut	13	14	15	16	17	18
S	Fill	19	20	21	22	23	24

*Herb--herbaceous cover present; no herb--no herbaceous cover present.
**Sample variable number designation.

Other information considered at each site included soil series, soil texture, parent material, elevation, percent slope, average annual precipitation, seed source (and distances to sources), and exact location of each site. "Soil" in this report refers to cut and fill material.

At each site, ten circular plots (133 sq. ft. or 12.33 sq.m) were sampled. Five samples were taken at sites where no woody plants were found or where there were large populations. All plots at the sample sites were permanently marked by wooden stakes or iron spikes. Records were kept as to the location of each woody plant species within each plot. Height and width measurements were taken, and records were made of herbaceous plant cover and composition. There were so many plants in some samples that numbers were estimated.

RESULTS

Woody plant invasion was highly erratic. This variability was traced to several factors: 1) the seed bearing characteristics of the plant species, 2) the distance and location of seed sources, 3) the conditions on the slope (particularly slope stability and the amount of hard rock present), and 4) the intensity of the herbaceous competition. Rainfall and competition did not appear to be critical factors. Seedling damage by insects and animals was less evident in natural invasion plots than in artificial plantings.

Plant Species

Only a few plant species were present in each study area. Plant species, numbers, and frequencies of occurrence (number of plots in which the species appears) at the different sample sites are shown in Tables III-2 through III-5. These tables indicate most of the invasive plant species within the sample areas.

In the Sierra Nevada Mountains (West), under favorable conditions, Ponderosa pine, Jeffrey pine, white fir, red fir, incense cedar, and lodgepole pine quickly invaded the rough slopes. These species made up 97% of the woody plants sampled. Deerbrush ceanothus, greenleaf manzanita, and gooseberry are commonly seen along roadsides. However, these plants made up only 2% of the species counted. Coniferous trees far outnumbered these shrub species.

22. Cut slopes on the west side of the Sierra Nevada Mountains are often better vegetated than fills since they are situated immediately below seed sources.

Table III-2. Woody plant species at 15 sample sites in the Sierra Nevada Mountains (West)

Species	Total Number	Number of Plots Where Found
Ponderosa pine	2881	7
Jeffrey pine or white fir*	562	3
White fir	1	1
Incense cedar	308	5
Grand fir	88	1
Sierra gooseberry	38	4
Deerbrush	31	3
Lodgepole pine	28	2
Whitethorn	12	3
Common manzanita	11	3
Mountain misery	7	3
Bitter cherry	6	2
Currant (unknown species)	6	1
Blue elderberry	4	2
Whiteleaf manzanita	4	1
California coffeeberry	4	1
Interior live oak	2	1
Snowberry	2	1
Antelope bitterbrush	2	1
Poison oak	2	1
Sugar pine	1	1
Black oak	1	1
Golden fleece	1	1

*Investigators did not differentiate between species in seedling stage.

In the Sierra Nevada Mountains (East), big sagebrush, rubber rabbitbrush, Jeffrey pine and bitterbrush made up 96% of the plants sampled. Big sagebrush and rubber rabbitbrush accounted for 87%, bitterbrush 4%, and Jeffrey pine 5% of the total. Slopes on the eastern side were drier and more densely populated with shrubs than slopes on the western side.

Table III-3. Woody plant species at 25 sample sites in the Sierra Nevada Mountains (East)

Species	Total Number	Number of Plots Where Found
Big sagebrush	959	10
Rabbitbrush	370	11
Jeffrey pine	66	12
Antelope bitterbrush	60	10
Greenleaf manzanita	23	5
Snowbrush	7	4
White fir	6	2
Currant (unknown species)	9	4
Mountain mahogany	4	3
Quaking aspen	4	1
Rose (unknown species)	5	1
Snowberry (unknown species)	2	2
Serviceberry	2	2
Willow (unknown species)	2	2
Phlox (unknown species)	2	2
Penstemon (unknown species)	1	1
Desert peach	1	1
Sage (unknown species)	1	1

23. Few shrubs invade grassy road slopes in the oak grasslands of the Sierra Nevada Foothills.

In the Sierra Nevada Foothills, interior live oak, digger pine, buckbrush ceanothus, mountain mahogany (mostly in the southern part of the area), and whiteleaf manzanita made up 91% of 11 woody species sampled. Douglas oak, the most visible species throughout the area, was found in only one sample.

Along the dry and grassy edge of the low-elevation, woodland foothills there are many miles of highway without woody plant reproduction. Areas at higher elevations have considerably more woody plant seedlings, particularly under parent trees and in areas where birds have dropped seed. At higher elevations, shrub and tree seedlings were growing in the spray strip near the road's edge where herbaceous vegetation has been removed for fire control.

Table III-4. Woody plant species at 30 sample sites in the Sierra Nevada Foothills

Species	Total Numbers	Number of Plots Where Found
Interior live oak	10	5
Birchleaf mahogany	15	2
Buckbrush	8	3
Digger pine	7	3
Poison oak	5	2
Whiteleaf manzanita	4	2
Yerba santa	1 (40 stems)	1
Ponderosa pine	1	1
Valley oak	1	1
Scrub oak	1	1
Dwarf flannelbush	1	1

In the Mojave Desert, four of the 19 species identified made up 89% of the plants sampled. These four were desert saltbush, cheesebush, creosote bush and burrobush. Cheesebush seems to be the most vigorous invader. It replaces rubber rabbitbrush and to some extent big sagebrush in lower rainfall areas. Desert saltbush invades low-lying salty areas. Creosote bush and burrobrush, found in almost 85% of the desert, readily invade disturbed sites. Other important species are fourwing saltbush, often found near watercourses; shadscale, found on alkaline flats and slopes; rabbitbrush, occurring on disturbed soils in higher rainfall areas; California buckwheat, also in higher rainfall zones but in the mountainous areas; and bush encelia which is confined more to dry, rocky slopes.

The amount of invasion onto disturbed areas seems to be directly related to the natural density of plants outside the disturbed areas.

Table III-5. Woody plant species at 31 sample sites in the Mojave Desert

Species	Total Numbers	Number of Plots Where Found
Desert saltbush	524	7
Burrobrush	133	8
Creosote bush	125	8
Bursage	71	10
Fourwing saltbush	45	3
Shadscale	33	3
Rabbitbrush	15	4
California buckwheat	14	4
Bush encelia	10	2
Desert alyssum	4	2
Wolfberry	3	3
Wiregrass	3	1
Broomsage	3	1
Spiny hopsage	2	2
Desert holly	2	1
Sweetbush	1	1
Spinescale	1	1
Cooper goldenbush	1	1
Cassia	1	1
Unidentified species	4	1

Distance to Seed Sources

Distances to seed sources were not easily determined. For example, it was not always possible to determine which of several plants was a parent. Also, specific sources were questionable when seed had been carried by birds and mammals or blown by the wind. Except for a few instances, potential parent sources were visible from the disturbed areas. Two species that produce light seed, rubber rabbitbrush and golden fleece, were probably carried by the wind from parent plants in the vicinity.

24. Many native shrubs on the east side of the Sierra Nevada Mountains produce seeds that are dispersed by the wind. Both cut and fill slopes have an equal chance of receiving wind-blown seed.

Seed appearing in animal and bird droppings could have been carried long distances even though there are seed sources of the same species nearby. Seedlings of Douglas oak and digger pine, both of which emerge from large seeds, were occasionally found several hundred feet from mature trees. Bitterbrush and Jeffrey pine seedlings were often observed growing in small groups several feet from parent plants. These seedlings were probably growing from rodent caches. When seedlings could be traced to a parent, the greatest numbers of seedlings were within the fallout area beneath parent branches. The numbers of seedlings dramatically decreased beyond the fallout zone. Cut slopes beneath parent trees consistently had more seedlings than fill slopes that were to the side or above parent plants. On cut slopes at the Ellis Road site, Jeffrey pine, incense cedar and white fir seedlings were so numerous that they would probably prevent the establishment of additional seedlings. The large number of big sagebrush seedlings growing around a solitary parent plant on a fill slope on Kingsbury grade shows how effective a short distance to seed source is to plant invasion. The seedlings were offspring from a primary invader.

Although most natural revegetation comes from seed, some plants do originate by other means. At the Tonzi Road site in the Sierra Nevada Foothills, 44 stems of yerba santa originated from the rhizomes of one parent plant. Poison oak at several locations grew from root sprouts. Near Red Bluff a flannelbush plant was observed growing from the main root below the original crown. Root sprouts from the Tree of Heaven were observed at several locations along Highway 49.

In Lake County, numerous plants of chaparral pea were observed growing on a cut slope from several roots. On one cut at Red Rock Canyon in the Mojave Desert, sprouts emerged from roots of Anderson desert thorn and armed senna.

Plant Size

Plant size is important from the standpoint of aesthetics, screening and erosion control. It was difficult to determine the average size of plants of the same age since plant species within the same apparent age group varied greatly in height. Height growth can be influenced by many factors such as the type of parent material, the soil depth and plant density.

The amount of early growth was similar for most woody species observed. Plants were generally less than 6 inches (15 cm) high at the end of two years. Shrubs when nearing maturity at about six years ranged from 2 to 5 feet (0.6-1.5 m) in height. Conifers varied from 3 to 15 feet (0.9-4.6 m) in height at about 15 years of age. Pine trees grew fast, particularly digger pine in the Sierra Nevada Foothills and Ponderosa and Jeffrey pine in the Sierra Nevada Mountains. Pines should be encouraged since they grow rapidly and drop needles that act as a blanket to protect the soil surface from erosion.

Plant Age

Plants vary in age on most slopes, since plant invasion tends to be a continuous process rather than a one-year event. When conditions are favorable, plants probably invade and occupy an area to create an evenly aged stand.

Under less than favorable conditions, plants invade more slowly and produce nonuniform stands of uneven age. At the favorable Mark Twain site there is an even aged stand of bonzai-like Ponderosa pine with many living and dead seedlings. At the Ellis Road site, seedlings of pine, fir and incense cedar thickly populated a slope during the first year following construction. In contrast, invasion into a dense cover of seeded perennial grasses on a fill slope on Kingsbury grade was slow. Invasion accelerated as a few early shrubs cast seed and plant numbers began to increase. On the Backus and Dawn Road overpasses near Lancaster, records show plants to be of uneven age. Within inventory plots new seedlings appeared and old plants died within a two-year span. This unevenness of ages indicated that natural revegetation of denuded areas is a continual and dynamic process.

Herbaceous Cover

In all study areas, the average number of woody species generally decreased as the herbaceous plant cover increased, as shown in Table III-6. Sites on Ellis Road, in the Sierra Nevada Mountains (West), were notable exceptions. On a north-facing cut, 504 seedlings were found. The reason for this high number may be that woody plant seedlings started growth at the same time as the grasses. On fill slopes where grass cover was as high as 90%, shrub numbers decreased to 259. The Ellis Road sites were located at an elevation where rainfall is high and the growing season is short. These conditions aid woody plant invasion since plants are not stressed for moisture as they are at lower elevations. These inventory sites were new when sampled and the plant situation may change.

Table III-6. Average number of woody plants relative to percent soil covered by herbaceous species

Study Area	Percent of Soil Covered by Herbaceous Species				
	0-20%	21-40%	41-60%	60-80%	80+%
Sierra Nevada Mountains (West)	390	0	45	261	-
Sierra Nevada Mountains (East)	54	146	19	12	-
Sierra Nevada Foothills	5	2	0	1	0
Mojave Desert	21	8	2	2	-

In the Sierra Nevada Foothills, woody plant counts were consistently low. The herbaceous cover was often 80% or more. The heavy cover of grasses and forbs partially accounted for the low density of woody plants. Past studies show that annual grass competition is devastating to young woody plants as well as to young perennial grasses (1). In the Sierra Nevada Foothills, more young oaks were observed growing within a narrow spray strip along the highway edge than in adjacent grassy areas. Woody plant counts were negligible at the Amador and Stanislaus River sites where annual and perennial grass covers were about 80%.

PHYSIOGRAPHIC INFLUENCES ON NATURAL PLANT ESTABLISHMENT

Exposure

As indicated by in Table III-7, severe hot, dry conditions on south facing slopes lead to low plant densities compared to northern exposures. In the Mojave Desert, however, such differences were small. These slight differences might be due to low humidity and rapid drying of the soil on both north and south exposures.

Table III-7. Average number of woody plants on north and south exposures in each study area

Study Area	North Exposure	South Exposure
Sierra Nevada Mountains (West)	499	63
Sierra Nevada Mountains (East)	93	30
Sierra Nevada Foothills	3	1
Mojave Desert	32	29

Cut and Fill Slopes

Although one would expect to find more woody plants on the mechanically pulverized and finer soil materials of fill slopes than on cut slopes, this was true only in the Sierra Nevada Mountains (East) and in the Mojave Desert as shown in Table III-8. There is little doubt that higher plant numbers on cut slopes in the Sierra Nevada Mountains (West) and the Sierra Nevada Foothills are the result of seeds falling from parent plants immediately above. Most of the seeds in these latter two areas are large and heavy and fall close to the seed source. In contrast, in the Sierra Nevada Mountains (East) and the Mojave Desert, there are more plants on fill slopes than on cut slopes. This is probably due to the small size and great number of seeds from plants such as those of the Compositae family. These seeds possess wind dispersal attachments. On the new portion of Highway 89 between Woodfords and Markleeville, a few rubber rabbitbrush seedlings were observed where no parent plants existed.

25. Where both cut and fill slopes receive equal amounts of wind-blown seed, fills usually provide better growing conditions for woody plants.

Table III-8. Average number of woody plants on cut and fill slopes in the study areas.

Study Area	Cut Slope	Fill Slope
Sierra Nevada Mountains (West)	391	86
Sierra Nevada Mountains (East)	43	92
Sierra Nevada Foothills	2	1
Mojave Desert	20	40

Average Annual Precipitation (AAP)

In the Sierra Nevada Mountains (West), the Sierra Nevada Mountains (East), and the Mojave Desert, plant numbers decreased as AAP increased. These numbers are shown by study area in Table III-9. As precipitation increases, plant species are usually replaced by species of larger growth forms.

Table III-9. Average number of woody plants in different rainfall zones.

	Average Annual Precipitation (inches)										
Study Area	4	5	6	7	8	20-24	25-31	31-40	41-45	46-50	55+
Sierra Nevada Mountains (West)								585	26	132	
Sierra Nevada Mountains (East)						286	29	14			
Sierra Nevada Foothills						1	2				
Mojave Desert	5	11	11	2	2						

In the Sierra Nevada Mountains (West), the greatest number of plants, mostly Ponderosa pine, were found in the low-elevation, timber-producing areas. These areas have higher precipitation, longer growing seasons and more moderate temperatures than do the high elevation Sierra Nevada Mountains. In the Sierra Nevada Mountains (East), Jeffrey pine numbers decrease with a decrease in precipitation as shrubby vegetation becomes denser.

In the Sierra Nevada Foothills, plant numbers increased with an increase in AAP. The oak woodland that fringes the Sacramento-San Joaquin Valley becomes denser with an increase in elevation and precipitation. More seed is made available as plant numbers increase and the natural revegetation potential becomes greater. At higher elevations within the oak woodland more aggressive shrubs are present which provide abundant seed for eventual plant invasion of disturbed areas.

In the Mojave Desert, there were more plants inventoried in the 5- to 6-inch (13-15 cm) AAP areas than in either the 4-inch (10.0 cm) or the 7- to 8-inch (18-20 cm) zones. Generally, plants are quite numerous in the desert except in the areas of lowest rainfall such as the floor of Death Valley. In places, rainfall can be too low to support vegetation. On mountain slopes within the 7- to 8-inch (18-20 cm) AAP zone, plant species such as cacti are not aggressive and plant numbers are even lower than in the low, salty areas of the 5- to 6- inch (13-15 cm) zone.

Elevation

The relationship between elevation and precipitation is well known, that is, precipitation increases with elevation. Temperature and length of growing season also change with elevation and affect plant development. Generally, plant counts were high in the Sierra Nevada Mountains (West) between the 3,000- and 6,000-foot (915-1830 m) levels. Plant numbers were also high at the upper elevations of the Sierra Nevada Foothills between 1,600 and 3,500 feet (488-1067 m) and at lower elevations of the Mojave Desert between 2,000 and 3,000 feet (610-915 m). In the Sierra Nevada Mountains (East), however, there were no clearcut trends. Higher plant numbers did not necessarily coincide with higher elevations. High plant numbers were observed on Kingsbury grade where the forest species gave way to shrubs as elevations and precipitation dropped.

Table III-10. Average* number of woody plants at different elevations

	Elevation (Feet)									
Study Area	300-800	800-1200	1200-1600	1600-3500	2000-3000	3000-4000	4000-5000	5000-6000	6000-7000	7000-8000
Sierra Nevada (West)					29	722	-	187	0	77
Sierra Nevada (East)						79	5	32	198	
Sierra Nevada Foothills	1	1	1	8						
Mojave Desert					35	4				

*Average is for 10 sample plots or 1,330 square feet (123 square meters). To convert to plants/acre, multiply by 32.75; to convert to plants/hectare, multiply by 72.

Soils

In mountainous and desert areas, natural soils are usually destroyed or buried during highway construction. The growth medium is mostly parent material. Cut slopes range from hard rock to fragmented parent material. Fill slopes often consist of pulverized rock, packed gravel and other debris.

Soil texture. The loose material on cut and fill slopes is usually gritty, fragmented parent material or gritty alluvium. Most of the soils encountered were loamy sands, sandy loams, or sandy clay loams. In the Sierra Nevada Mountains there are few sandy or clay-like soils. In the Mojave Desert, there are many sandy soils but few clays. On fill slopes, gravel combined with fine material often forms a matrix between cobbles, stones and boulders. On cut slopes this fine gravelly material will form a thin mantle over a hard surface.

In the Sierra Nevada Mountains (West), the highest numbers of woody plants were found on loamy textured granitic parent materials between the 4,000- and 6,000-foot (1220-1830 m) levels. This is a belt of good precipitation and rapid snow melt. These soil materials are deeply weathered, primarily through chemical processes, and account for the loamy texture and soft bedding medium favorable to plant growth.

Parent material. In the Sierra Nevada Mountains (West), the highest plant counts were made on chemically decomposed granite and granodiorite parent materials. If slopes were steep but stable, plants were able to grow. Plant numbers were high on stable granite fill slopes in the Sierra Nevada Mountains (East). Good plant growth was observed on fine-grained dark basic material. Counts were much lower on hard, steep, granite cut slopes. The lowest plant numbers were seen on mixed colluvium. Road slopes through colluvial material were constructed only recently.

In the Sierra Nevada Foothills, the highest plant numbers were on metasedimentary and granite material. Low plant counts were made on serpentine and the sandy clay material of the Ione formation.

In the Mojave Desert, the highest plant densities occurred on colluvial material. Few woody plants were observed growing on hard granite parent materials.

26. Some soils are erosive, sterile and droughty. Decomposed granites usually provide poor growing conditions for woody plants.

SLOPE TREATMENTS THAT INFLUENCE WOODY PLANT INVASION

Trials made as part of this study and during the 1970-75 CALTRANS-SCS study were observed to determine which slope treatment effectively encouraged woody plant invasion. Table III-11 summarizes these observations.

Table III-11. Treatments that influence woody plant invasion

Treatment/Location	Year	Results/Comments
Fertilization Highway 49, San Andreas	1980	Serpentine soil, encouraged grasses to the detriment of shrubs*
Mulching Highway 49, San Andreas	1980	Serpentine soil, encouraged grasses to the detriment of shrubs*
Fertilization Various SNF locations	1970-74	Fertilized grasses inhibited the establishment of woody plants*
Fertilization Highway 395, Alturas	1972-73	Fertilized ares were densely populated with invading shrubs
Jute Matting, Straw Highway 395, Ridgecrest	1980	No effect
Fertilization Highway 395, Ridgecrest	1980	Fertilized areas were densely populated with invading shrubs
Scarification Highway 395, Ridgecrest	1981-82	No effect; scarification lost due to shifting sand
Topsoiling Highway 50, South Tahoe Airport	1973	Shrub seed carried with topsoil, excellent cover of shrubs
Fertilization-Mulching Crystal Springs, San Mateo County	1971	Coastal environment allowed invading coyote brush to take advantage of fertilizer and mulch

*Treatments to encourage shrub growth in the Sierra Nevada Foothills almost always increase the growth of herbaceous plants. Growth of herbaceous plant materials in turn severely limits the establishment of woody plants.

TREATMENTS TO ENCOURAGE THE NATURAL INVASION OF WOODY PLANTS

It may be possible to treat highway slopes during the construction phase so that they assume characteristics conducive to natural woody plant invasion. As part of this project, several small trials and observations were conducted to determine what might be done to encourage rapid woody plant invasion.

Treatment Methods

During the winter of 1980 nine slope treatments were applied to a west- and an east-facing cut slope on U.S. 395 near Ridgecrest, CA (P.M. 20.5, Kern). Treatments are listed in Table III-12. These slopes are very similar to those on which the seeded plots and container plants were established near P.M. 18.8 Kern. Surrounding vegetation is primarily creosote brush, desert saltbush, bursage, rabbitbrush, cheatgrass and Arabian grass.

Table III-12. Treatments applied to a highway cut and fill slope near Ridgecrest, to encourage the natural invasion of woody plants

1.	Mechanical scarification (by hand rake and hoe)
2.	Fertilizer, 16-20-0 at 250 lbs/acre (273 kg/ha)
3.	Straw, 4,000 lbs/acre (4364 kg/ha)
4.	Jute matting
5.	Mechanical scarification plus 16-20-0 fertilizer at 250 lbs/acre (273 kg/ha)
6.	Mechanical scarification plus straw at 4,000 lbs/acre (4364 kg/ha)
7.	Mechanical scarification plus jute matting
8.	Fertilizer, 16-20-0 at 250 lbs/acre (273 kg/ha), and straw, 4,000 lbs/acre (4364 kg/ha)
9.	Fertilizer, 16-20-0 at 250 lbs/acre (273 kg/ha), and jute matting

27. Several fertilizer and mechanical treatments were applied to road slopes near Ridgecrest to observe their effects on natural plant invasion.

Results and Discussion

No woody plants were observed growing in treated plots or on untreated sections of the slopes during the three years following treatment. Some plants may have germinated and been browsed by rodents between observations, but no evidence was seen to support this possibility. The jute mat plots were the only treatments remaining in March 1983. These plots should be reviewed periodically to see if there has been any change.

The straw plots remained for one year. Straw had been crimped with a spade but strong winds removed most of the straw between spade grooves soon after establishment. A tackifier would have been more successful.

Road slopes are often void of natural vegetation because the soil surface is unstable. Material on these slopes had been moving continually because of wind and water action. Scarification treatments were attempts to stabilize the soil surface so as to catch seed and moisture. Unfortunately, all signs of scarification were gone soon after treatment as wind and rain smoothed the rough surfaces. More severe scarification is needed if this type of treatment is to be successful.

The application of fertilizer to road slopes has often been effective in encouraging woody plant growth. However, no shrubs were seen within these fertilizer treatment areas. At several other planting sites, native shrubs were observed growing within seeded and fertilized plots. However, native woody plants will often take advantage of the good growing conditions created by fertilizer and mulch treatments. A combination of severe scarification or benching and fertilization may be a practical and effective means to encourage natural woody plant growth.

28. Fertilizer will sometimes be sufficient to encourage natural woody plant invasion. Shrubs readily occupied this fertilized highway slope south of Alturas.

CONCLUSIONS AND RECOMMENDED PRACTICES

Conclusions

Woody plant invasion onto highway cut and fill slopes can be a slow process. The major factors affecting the invasion rate appear to be 1) herbaceous competition, 2) availability of seed, and 3) slope conditions (slope angle, aspect, stability, etc.). Within each of the study areas the majority of woody plants inventoried were represented by only a few species. Species of the same age varied widely in size, depending upon site conditions. Natural invasion is continuous as some plants die and others become established.

Invasion rate is dependent upon the plant species present and the distance to seed source. Seeds of some species have specialized attachments which allow them to be carried by the wind. Seedlings of rabbitbrush were found far removed from parent plants. Seedlings of large seed producers such as pines and oaks were most often found within the fallout area beneath parent plants. Large seeds were sometimes transported away from their points of origin by birds and mammals.

The vigorous growth of annual grasses can prevent the establishment and growth of woody plant seedlings. In high rainfall areas shrubs and trees did survive where they were able to start growth about the same time as perennial grasses.

North-facing slopes support a greater density of woody plants than south-facing slopes. More plants were observed growing on cut slopes than on fill slopes. Cut slopes are often constructed beneath natural seed sources whereas fill slopes are situated above existing vegetation.

Woody plant numbers generally decreased as precipitation increased. Two exceptions were in the Sierra Nevada Mountains (East) and the Mojave Desert. In the Sierra Nevada Mountains (East), Jeffrey pine numbers decreased and shrubs increased as the rainfall lessened. High densities of desert saltbush plants were observed in low rainfall zones of the Mojave Desert. There were more plants at higher elevations.

Relationships between soil series and plant numbers could not be determined since soil profiles were usually destroyed during highway construction. The material comprising roadslopes is mainly gritty fragmented rock or sand. The highest densities of woody plants were found on loamy textured materials in the Sierra Nevada Mountains. The degree of weathering of the slope material seems to influence plant growth more than the actual material itself. No plants were growing on rock or cemented alluvium.

Unstable slopes usually do not contain woody plants. Surface erosion will displace soil, seed and plants. Established seedlings can be covered by shifting soil.

Recommended Practices

The results of this study should aid engineers and designers during the planning phases of highway construction. Planners should be able to make more accurate estimates of the species and numbers of woody plants that can be expected to invade a proposed project site.

29. Gentle fill slopes furnish ideal conditions for woody plant invasion.

Slope stability is a necessity. Where instability is a potential threat, measures must be taken to prevent soil movement if woody plant invasion is to be encouraged. Herbaceous seedlings can prevent surface erosion but grass covers will not stop the movement of large masses of soil.

30. Slopes must be stabilized if woody plants are to grow. Little natural invasion will occur when the growing medium is constantly moving.

The decision as to the type of vegetative treatment to use should be made on a site-by-site basis. Following an analysis of the soil or parent material, a planner could decide whether to modify seeding mixtures and rates to encourage woody plant invasion or to undertake a more intensive containerized planting program. As shown by the study, some soils and site situations are not receptive to rapid woody plant invasion.

Some areas within the brushlands of the Sierra Nevada Foothills and coniferous forests of the Sierra Nevada Foothills may require treatment if natural invasion is to take place. Other areas do not need such consideration. Seedings of herbaceous plant materials are usually sufficient in areas such as the oak woodland of the low elevation Sierra Nevada Foothills.

31. Steep slopes must be benched or laid back if there is to be any hope for natural woody plant growth.

In addition to information supplied by this study, on-site observations of adjacent roadbanks or excavated areas will give indications of what to expect in the way of woody plant invasion. Futhermore, where conditions are conducive to natural plant invasion, success can be expected from artificial shrub or tree plantings. In situations where natural revegetation is unlikely, artificial plantings must be given more intensive care to insure establishment. Table III-13 summarizes the slope conditions that were found to favor or not favor natural plant invasion.

Table III-13. Factors that affect the natural invasion of woody plants onto highway slopes.

Favorable Factors	Unfavorable Factors
Stable slope material, angle less than the angle of repose	Unstable slope material, angle greater than the angle of repose
Porous or fragmented slope material (cut slopes)	Hard, rocky slope material with few fines
Loamy textured material derived from metasedimentary or granitic material*	Slopes comprised of serpentine or sandy clay material**
Slopes comprised of colluvial type material#	Slopes of hard or cemented granitic material#
Rough slope surface	Smooth slope surface
Low density of herbaceous cover	High density of herbaceous cover
North or east exposure	South or west exposure
Seed source nearby or above disturbed areas	Seed source distant or below disturbed areas

* Sierra Nevada Mountains
** Sierra Nevada Foothills
\# Mojave Desert

IV REVEGETATION OF PROBLEM SOILS

Most nonirrigated areas in California can be seeded or planted using standard revegetative techniques. Some soils, however, possess severe limitations which make them difficult to revegetate. Five of these soils are serpentines, soils of low or high pH, soils with a high boron content, decomposed granites and volcanic tuffs.

Generally, highway cuts and fills through these types of soils occupy little acreage. The effort necessary to revegetate them, however, can be costly and intensive. The term 'problem soil' in this discussion refers to a soil that is difficult to vegetate due to its structure or some toxic substance or element. The problem soils dealt with during the project were those most commonly encountered by Caltrans during highway construction. The main emphasis in the study was to find plant materials that were adapted to these difficult growing conditions. Some slope treatments were made for comparative purposes.

The testing locations were:

State Highway 49, 1 mile (1.6 km) N of San Andreas, Cal-49, PM 25.0
State Highway 124, 6 miles (9.6 km) NE of Ione, Ama-124, PM 6.75
I-80, 2 miles (3.2 km) N of Vallejo and State Highway 16 at the Sacramento-Amador County line, Sol-80, PM 9.5 (plantings in cooperation with Caltrans Transportation Laboratory)
U.S. 395, 16 miles (25.6 km) N of Bishop, Mono-395, PM 3.3
U.S. 395, 5 miles (8.0 km) S of Little Lake, Inyo-395, PM 5.5
U.S. Borax property, Boron

At most locations both direct seedlings and container plantings were made.

STATE HIGHWAYS 49 AND 124 (SERPENTINE SOILS)

Slopes at these two sites were comprised of loose to rocky weathered serpentine. The sites have been described as ultrabasic intrusive rock with a pH of 8.6. Serpentine soils have always been difficult to vegetate due to their infertility and high magnesium-to-calcium ratio. Both of these slopes are east facing and represent the type of serpentine situations encountered during highway construction in the Sierra Nevada Foothills. Average annual precipitation is 25 inches (63.5 cm) and the dominant surrounding vegetation is annual grassland interspersed with Ponderosa pine, digger pine, chamise, buckbrush, toyon, scrub oak and blue oak.

Direct Seedings

Methods of establishment. Standard seeding, mulching and fertilization techniques were employed wherever possible. On Highway 49 during the fall of 1980, five annual grasses and five woody species were both broadcast seeded (before mulching) and seeded by hydromulching. Fertilization and mulch plots containing no seed were also included as part of the study.

Since first-year results from the 1979 seeding were encouraging, fall plantings in 1980 were made on a cut slope on Highway 124 as well as Highway 49. Annual grasses, perennial grasses and woody plants were included in this seeding.

In 1981, several slope treatments were included in the testing. Two depths of topsoil and one treatment of lime were applied over the serpentine material on Highway 49. Five grass species (three plots each) were seeded over each of the three treatments. One plot was fertilized with 16-20-0, a second with magnesium ammonium phosphate (Mag Amp) fertilizer and the third plot was left unfertilized as a control. Plots were 3 x 3 feet (1.0 x 1.0 m) in size.

In the winter of 1981, 28 species of shrubs and trees were seeded in furrows on Highway 49. Seeds of woody species requiring special treatment to enhance germination were treated at the Lockeford PMC prior to treatment. Ten-foot-long (3.0 m) furrows spaced 3 feet (1.0 m) apart were seeded. Seed was covered with soil.

Seeding rates in all plots were 40 lbs/acre(43.6 kg/ha); mulch rates were 2,000 lbs/acre (2182 kg/ha); 16-20-0 fertilizer rates were 500 lbs/acre; (545 kg/ha); and Mag Amp rates were 1,000 lbs/acre (1091 kg/ha). Topsoil depths were 1" and 4" (2.5 cm and 10.2 cm). Lime was applied at a rate of 7 1/2 tons per acre (6.82 metric tons). Plot size was either 10 x 20 feet (3.0 x 6.1 m) or 20 x 20 feet (6.1 x 6.1 m) unless specified otherwise.

Results and species adaptation. Results from the 1979 annual grass seedings on Highway 49 were excellent during the first year following seeding. 'Blando' brome was the most vigorous grass early in the growing season. As the season progressed the growth of 'Wimmera 62' ryegrass exceeded 'Blando' brome, 'Zorro' annual fescue, quaking grass and red brome. No differences were seen between plots that had seed applied as part of the mulch slurry and plots that had the seed broadcast before mulching. No woody plants were observed during the first year following seeding. The growth of herbaceous vegetation within the nonseeded fertilized plots was also very good. Seeds blown from surrounding areas germinated and plants took advantage of the fertilizer and mulch. Growth and cover compared favorably with the seeded plots.

32. Annual grasses produced lush growth on serpentine soils (left) during the first growing season but growth stagnated in the second year (right) as fertility was exhausted.

By the end of the second growing season very little grass growth was observed in any of the plots. The annual grasses had germinated but only reached a height of 3 inches (7.5 cm). Apparently, plants had exhausted most of the available nitrogen during the first year of growth.

Plants of California buckwheat began to appear during the second growing season (1980). These seeds had delayed germination during the first year or plants had been overlooked.

The Highway 124 site was planted in the fall of 1980. Seeded annual grasses and legumes showed fair growth during the first growing season. 'Lana' woollypod vetch, rose clover, 'Blando' brome and 'Wimmera 62' ryegrass produced fair covers. No perennial grasses or woody plants were observed. By the end of 1982, no seeded species remained. Some indigenous herbaceous species took advantage of the fertilizer and were present until 1982.

The response from the 1981 fertilized topsoil and lime treatment on Highway 49 was as expected. Two perennial grasses, 'Berber' orchardgrass and 'Goar' tall fescue, grew well in the 4-inch (10.2 cm) topsoiled plots. 'Zorro' annual fescue and 'Blando' brome also produced excellent stands. Red brome showed only fair vigor and growth.

Growth of all grasses was best in the 4-inch (10.2 cm) topsoil plots fertilized with 16-20-0. The 4-inch (10.2 cm) topsoil plots fertilized with Mag Amp fertilizer ranked second. Growth in the unfertilized control plots was depressed. Overall growth was ranked best in the 4-inch (10.2 cm) topsoil plots and third in the limed plots.

The only plant species that persisted from the earliest direct seeding trials (1979) was California buckwheat. In 1982, plants averaged 4 inches (10.2 cm) in height. Toyon was the only woody plant species to emerge from the 1981 direct seeding trial (seeded within furrows). Only four plants were observed and none survived.

Container Plantings

Methods of establishment. Seeds and cuttings from plants growing on serpentine soils were collected when possible. A literature search at the beginning of the study produced a list of plant material that showed potential for use on serpentine soils. Plants not purchased were propagated at the Lockeford Plant Materials Center. Attempts were made to obtain plants from commercial sources that could provide information as to the natural origin of the plant materials.

Container plants were grown in either gallon cans or book binders (1-1/2 x 1/2 x 8", 3.8 x 3.8 x 20.3 cm, plastic root trainers). Shrubs and trees were from 9 to 12 months old at the time of planting. Some bareroot and balled stock were transplanted from serpentine soils to the test sites. A bucket-type posthole digger was used for bareroot and balled stock. Several perennial grasses were grown and established as container plants. A 4-inch (10.2 cm) auger was used to prepare holes for book binder plants. Two ounces (57.0 gm) of Mag Amp fertilizer were mixed with the bottom backfill prior to planting. Soil was then firmly packed around plants to remove air pockets. All plants were given one gallon (4.0 liters) of water at the time of planting to wet the backfill and to firm the soil around the roots.

Plantings were generally made from November to January. Soil is moist and many plants are dormant at this time of the year. Late fall or early winter plantings allow plants to acclimate themselves sufficiently to take advantage of early spring growing conditions.

Results and species adaptation. Between 1980 and 1982, 937 container and balled plants were planted. Some of the species planted grow naturally on serpentine soils. Others showed tolerance to such adverse conditions as drought and high pH, and it was thought that they might also grow on serpentine soils.

However, by March, 1983 only 103 plants had survived. At the time of the last evaluation, all plants had been growing for more than one year. No plants were irrigated. Thirty-one of the surviving plants were grasses. Three of these were natives. 'Largo' tall wheatgrass, an introduction, showed the highest percentage of survival of any species, either herbaceous or woody. 'Luna' pubescent wheatgrass looked fair and showed some rhizomatous activity. Four plants of smilo showed vigorous growth.

33. Planting perennial grasses from containers was successful on the serpentine cut north of San Andreas.

Seventy percent of the 'Berber' and 40% of the 'Palestine' orchardgrass plants survived for more than one year. 'Berber' was more vigorous and produced more foliage than 'Palestine'. Three plants of Harford melic were alive in March, 1983 but lacked vigor. The melic accessions were raised from seed collected from parent plants growing on serpentine soils.

Of all the woody plants tested, the pines, saltbushes and California buckwheat performed the best. Thirteen percent of the Jeffrey pine, 17% of the Ponderosa pine, 20% of the Coulter pine and 37% of the digger pine survived. Mortality among the pines was high but plants that survived looked healthy and vigorous. Pines attained little height growth, but spread laterally.

34. Digger pine (left) and California buckwheat (right) are two woody species that showed potential for growth on serpentine soils.

Fifty-seven percent of the 'Marana' fourwing saltbush and 53% of the oldman saltbush survived. 'Marana' grew in height but appeared weak and stressed. Oldman saltbush looked hardy.

California buckwheat was probably the best adapted of any woody plant tested on this serpentine soil. As mentioned earlier, it grew well from seed. Sixty percent of the container plants survived, produced abundant growth and remained vigorous through the last evaluation in March, 1983.

Several other shrubs may have potential even though their survival was low or growth so slow that their use was questionable. Serpentine manzanita did not look too vigorous even though three of the eight plants survived in March, 1983. Its performance could be partially attributed to the fact that it was transplanted from a serpentine soil to the test location, and the plants may not have had adequate time to adjust.

Two of the 15 Sargent cypress plants survived. One survivor was a 1981 transplant from serpentine soil and the second was a transplant from this same accession that had been potted and planted the following year.

Conclusions and Recommendations

Serpentine soils have always been difficult to vegetate. Furthermore, on highways the cut and fill materials are usually not soils but rather fragmented rock or parent material. The planting medium usually has a low water-holding capacity, an imbalance in the magnesium-to-calcium ratio, and is infertile.

Plants were to be screened to observe which species might possess characteristics that would allow them to adapt to the difficult growing conditions of serpentine soils. As seen from the discussion above, only a small percentage of the planted species survived. A smaller number yet responded well enough to be recommended for use on serpentine soils.

Serpentine sites along highways are usually small in acreage. A combination of container grasses and shrubs could be established on many of these sites quite easily. A road slope similar in size to the sites on Highway 49 could probably be planted by a six-man crew in one or two days. Table IV-1 suggests some possible species for use on serpentine soils. Four-foot (1.2 m) spacing for both grasses and woody plants should be adequate. The spacing will increase as plant numbers decrease through mortality.

Mag Amp fertilizer at a rate of 2 ounces (57.0 gm) per plant was applied at the time of planting. However, fertilizer should probably not be applied until the second year, since weedy vegetation can take advantage of the fertilizer and severely compete with newly established woody plants.

Table IV-1. Recommended container plants for use on serpentine soils in the Sierra Nevada Foothills

Woody Species	Herbaceous Species
Oldman saltbush	'Berber' orchardgrass
California buckwheat	'Largo' Tall wheatgrass
Digger pine	'Luna' pubescent wheatgrass
Jeffrey pine	Smilo
Ponderosa pine	
Coulter pine	
Serpentine manzanita	
Sargent cypress	

Only four native perennial grass species were planted at the site. Squirreltail was transplanted directly from a serpentine soil and the two Harford melic accessions were raised from seed collected from plants growing on serpentine soil. Plants of California fescue and blue wildrye were transplanted from nonserpentine sites. Even though the native perennials did not perform as well as introductions, more thorough screening of California native perennial grasses may produce a well-adapted strain.

COMPARISON OF PLANT GROWTH ON 15 SERPENTINE SOILS OF DIFFERENT ORIGIN - SPECIAL STUDY

Walker (9) differentiated serpentine soils from other soils by their high content of magnesium, nickel and chromium and their low content of total and absorbed calcium. Martin, Vlamis and Stice (6) in their study of a serpentine soil in Lake County found that seeded oats responded to the addition of gypsum. These responses occurred in the second through fifth years following treatment. The addition of nitrogen also produced increased growth in seeded grasses.

Proctor (8) found that oats grew differently on different serpentine soils. After evaluating several fertilizer treatments, Proctor concluded that the low calcium-to-magnesium ratio was the problem. To further test plant response to fertilizer treatments on serpentine soils, 15 serpentine soils from different areas of California were brought to the Lockeford PMC. Each soil was seeded with 'Blando' brome and subjected to several fertilizer treatments. Plant response was then observed.

Table IV-2. Description of serpentine soil sample sites

Sample Number	Location	County	Slope	Vegetation in Area
1	Lockeford PMC Field 2	San Joaquin	Level	Orchard, vineyards
2	Geysers. Near steamwell LG2	Sonoma	Cut	McNab cypress, knobcone pine
3	Geysers. Near steamwell DX 7.2	Sonoma	Cut	Jepson ceanothus, buckbrush ceanothus, leatheroak, chamise
4	Knoxville Road Near Homestake Mine	Napa	Cut	Chamise, buckbrush ceanothus, toyon, digger pine, Sargent cypress, whiteleaf manzanita, yerba santa
5	Knoxville Road	Lake	Undisturbed barren slope	Native forbs and grasses, Douglas oak, digger pine
6	Highway 20 PM 0.62	Colusa	Cut	Chamise, buckbrush ceanothus, digger pine, whiteleaf manzanita
7	Highway 20 PM 3.321 Berryessa	Colusa	Barren slope	Native forbs and grasses, chamise, toyon, scrub oak
8	Highway 128 Lake Berryessa	Napa	Cut	Native forbs and grasses, chamise, toyon, scrub oak
9	Crystal Springs Highway 92	San Mateo	Cut	Native forbs and grasses
10	Crystal Springs I-280 and Highway 92	San Mateo	Cut	Native forbs and grasses
11*	Ione Highway 124 PM 6.9	Amador	Cut	Chamise, whiteleaf manzanita, buckbrush ceanothus, digger pine, toyon
12*	San Andreas I Highway 49 PM	Calaveras	Cut	Native forbs and grasses, buckbrush ceanothus, digger pine, toyon
13*	San Andreas II Highway 49 PM	Calaveras	Cut	Same as above
14	Pine Mt. above San Simeon	San Luis Obispo	Cut	Manzanita (A.obispoensis), Sargent cypress, digger pine
15	Cuesta Ridge Botanical Area (edge)	San Luis Obispo	Cut	Manzanita (A.obispoensis), Sargent cypress, wartleaf ceanothus, monkey flower
16	Cuesta Ridge Botanical Area (inside)	San Luis Obispo	Fill	Same as above

*Plant testing sites

35. Fifteen serpentine soils from different areas of California were brought to the Lockeford PMC. Plant growth within the soils was recorded and compared.

Study Methods

Fifteen serpentine soils and one soil from the Lockeford PMC were compared. Locations of the serpentine soil sample sites are shown in Table IV-2. Soils were dried, screened to remove rocks larger than 0.25 inch (6.4 mm) and chemically analyzed. Chemical characteristics are shown in Table IV-3. Soils were placed in 1" x 5" (0.4 x 12.7 cm) plastic tubes, preirrigated, seeded with eight seeds of 'Blando' brome per pot, given the specified treatment, covered with vermiculite and placed under intermittent spray in the greenhouse. 'Blando' brome was used as an indicator plant since it is one of the most commonly seeded grasses for erosion control. Treatments applied to each soil are shown below:

Treatment	Rate
1. No fertilizer	
2. Ammonium phosphate sulphate, 16-20-0	500 lbs/acre (546 kg/ha)
3. Ground limestone, CaCO3	8,000 lbs/acre (8728 kg/ha)
4. Ammonium phosphate sulphate + CaCO3	Rates as in treatments 2 and 3
5. Ammonium phosphate sulphate + trace elements	Rates as in treatments 2 and 6
6. 'ESMIGRAM' trace elements + sulphur, boron, chloride, copper, iron	5.5 lbs/cubic yd (3.3 kg/m^3
7. Ammonium sulphate 20-0-0	400 lbs/acre (436 kg/ha)
8. Single superphosphate 0-20-0	500 lbs/acre (546 kg/ha)
9. Potassium chloride 0-0-60	100 lbs/acre (109 kg/ha)
10. Sulphur	1,680 lbs/acre (1833 kg/ha)

Results and Discussion

Calcium was low in all serpentine soils with the exception of sample 7. All serpentine soils except sample 7 had a lower calcium content than the nonserpentine Lockeford sample (see Table IV-3).

Soil sample 7 was collected from a hillside south of Williams on State Highway 20. It had a high concentration of calcium, magnesium, sodium and boron. These high cation concentrations, along with the high level of boron, probably accounted for poor plant growth in the area. The high mineral concentrations at this site may have originated from steam or water emissions rather than the serpentine parent material.

Magnesium was high in all serpentine soil samples. All samples were higher in magnesium than the nonserpentine Lockeford soil. The ratios of calcium-to-magnesium were not greatly out of balance for serpentine soils. The Lockeford sample was the only soil with a calcium-to-magnesium ratio greater than 1:1.

Except for site sample 7, phosphorus, potassium and boron from these sites were lower than in the Lockeford soil. The concentrations are generally low for optimum plant growth. Manganese was low in several samples. Zinc, copper and iron were adequate in all soils. Nickel and chromium were high but probably not to the point where they were toxic. Available molydenum was low in most samples (0.05 ppm).

As indicated in Table IV-4, early growth of 'Blando' brome on all soils was similar. Seventeen days after seeding all plants were healthy. Plants fertilized with nitrogen were 7 to 9 inches (18-23 cm) tall, whereas those growing in containers not fertilized with nitrogen were 3 to 5 inches (7.5-13 cm) in height. No differences could be seen in plant response between the nonserpentine Lockeford soil and the serpentine soils.

Table IV-3. Chemical characteristics of 15 serpentine soils and a control

Sample Site	Soil pH	Milliequivalents/Liter			Parts per Million (ppm)										
		Na[1]	Ca[1]	Mg[1]	K[2]	N[3]	P[4]	Zn[4]	Mn[4]	Cu[4]	Fe[4]	Cr[5]	Ni[5]	Mo[6]	Bo[7]
1	5.7*	0.51	2.5	1.2	111	14	24.0	12.1	38	10.7	51	21	30	35	0.07
2	7.4	1.18	1.5	5.4	19	13	18.0	11.4	20	0.83	14.5				0.04
3	7.3	0.35	0.1	1.3	7	10	2.3	0.75	2.3	0.19	7.5				0.04
4	7.4	0.40	0.3	2.6	26	6	2.6	1.2	6.8	0.51	18.0				0.11
5	7.6	0.69	0.5	3.9	27	7	5.9	1.0	12.1	0.66	32.6				0.03
6	7.8	0.77	0.6	3.8	14	12	3.2	1.0	3.7	0.28	6.2				0.19
7	8.0	15.5	10.0	14.7	24	14	2.6	0.9	1.6	0.45	16.1	252	1740	0.05	3.1
8	8.1	1.6	1.8	4. 6	27	6.5	2.2	1.1	4.4	0.53	9.7	119	360	0.05	0.04
9	8.1	1.34	0.6	3.4	52	8	4.6	6.4	4.9	0.70	9.8	693	1890	0.05	0.22
10	7.6	0.76	0.5	1.9	32	8	5.0	0.51	2.2	0.42	9.7	406	1580	0.05	0.13
11	7.7	0.96	0.7	3.9	61	5.5	6.1	3.7	15.5	0.77	10.9				
12	8.2	0.86	2.2	4.3	31	12	4.4	5.1	2.4	0.41	9.2	725	928	0.05	0.17
13	7.4	0.99	1.1	3.1	73	6.5	3.0	1.8	7.5	0.7	16.3	1020	2680	0.05	0.01
14	7.4	0.69	0.3	3.0	69	8	10.0	0.89	20.8	0.72	29.2				0.04
15	7.1	0.67	0.5	2.4	40	10	2.6	1.05	28.3	0.81	23.7				0.09
16	7.1	0.54	0.3	2.7	27	6.5	5.5	0.8	12.5	8.8	24.9				0.09

* Control, Columbia fine sandy loam from the Lockeford PMC.

1/ Saturated extract
2/ Ammonium acetate extract
3/ Nitrate nitrogen
4/ DTPA extractable
5/ Concentrated nitroc acid extraction
6/ Extraction from Tamm's Solution, acid ammonium oxalate (1 part soil to 10 parts Tamm's)
7/ Soluble boron from saturated extract

Table IV-4. Early height* growth of 'Blando' brome after the application of 10 fertilizer treatments to 15 serpentine soils and one control

Sample No.	Sample Location	Fertilizer Treatment** 1	2	3	4	5	6	7	8	9	10	Average
1	Lockeford PMC	3	4	4	7	#	5	5	7	7	6	5.5
2	Geysers	5	4	4	4	6	4	6	4	4	3	4.4
3	Geysers	4	5	3	4	7	4	4	5	4	3	4.3
4	Knoxville	3	7	4	4	6	5	5	4	4	4	4.6
5	Knoxville	5	3	5	5	8	5	6	5	6	3	5.1
6	Williams	5	7	5	4	6	4	4	3	4	4	4.6
7	Williams	4	6	4	3	7	3	5	5	4	4	4.5
8	Lake Berryessa	4	5	4	5	7	4	4	4	4	3	4.5
9	Crystal Springs Rd	3	10	5	4	6	6	7	5	5	4	5.5
10	Crystal Springs Rd	3	7	4	4	7	5	5	4	4	4	4.7
11	Ione	5	6	5	5	7	6	7	4	4	4	5.3
12	San Andreas	3	7	4	3	7	3	4	4	4	3	4.2
13	San Andreas	5	7	4	4	7	4	9	8	4	4	5.6
14	Pine Mountain	4	9	4	4	9	5	6	3	4	4	5.2
15	Cuesta Ridge	3	9	4	4	8	5	4	5	5	4	5.1
16	Cuesta Ridge	3	7	3	4	6	4	4	4	4	3	4.2
Average (rounded to next highest whole number)		4	7	4	4	7	5	5	5	4	4	

* Height in inches after 17 days growing interval.
** Fertilizer treatment described in text.
\# = no plants. Used 7 inches height growth figure.

The addition of ammonium phosphate sulphate (16-20-0) produced positive results in most soils. However, when calcium was combined with 16-20-0 fertilizer as a treatment, no fertilizer effects were noted. Single applications of phosphorus, potassium, sulphur, calcium or trace elements did not show any plant response. During the short time of this study calcium and sulphur may not have become available for use by 'Blando' brome. The pH values for all soils were well within the range of satisfactory growth for 'Blando' brome.

Conclusions

1. The chemical analysis showed that all serpentine soils except soil 7 were similar in chemical composition.

2. No early nutrient deficiencies were observed in any of the serpentine soils. 'Blando' brome responded the same to similar treatments on all soils. 'Blando' brome responded quickly on all soils to the application of 16-20-0 fertilizer.

3. 16-20-0 fertilizer, when accompanied by calcium, produced no response.

4. Single applications of phosphorus, potassium, sulphur, calcium and trace elements had no effect on plant growth.

5. This study produced results similar to those observed in plots north of San Andreas, where annual grasses responded to nitrogen fertilizer treatments.

Recommendations

1. Long-term revegetation of serpentine soils is needed. This study could be repeated using a perennial grass such as 'Berber' orchardgrass or 'Luna' pubescent wheatgrass to observe the long-term effects of serpentine soils on plant material.

2. Fertilizer trials, particularly calcium applications, should be conducted on existing serpentine slopes on a long-term basis. Observations should be made to determine whether a growth medium could be developed which would recycle nutrients and result in persistent vegetation. Most studies to date show that several years after treatment, serpentine soils revert back to their pre-treatment state.

INTERSTATE 80 (LOW pH SOILS)

The Caltrans Transportation Laboratory (Translab) has undertaken a water quality study on Interstate 80 north of Vallejo to determine mitigation measures for highway-related chemical water quality pollutants. SCS provided seed for plant materials trials as well as assistance with plant evaluations following stand establishment. This discussion deals only with plant materials. Details of the water quality study appear in a separate report.

Plantings were made on an east facing cut slope. The slope material has been described as fine-grained soft to moderately hard sandstone. Layers of lignite, lined with limonite, are embedded within the sandstones. Soil pH ranges from 4.2 to 6.4.

Average annual precipitation is 22 inches (55.9 cm). The dominant surrounding vegetation is annual grassland associated with isolated stands of coyote brush and California buckwheat.

Direct Seedings

Methods of establishment. Plots varied in size according to their position on the slope. Table IV-5 shows the sizes and summarizes treatments. Seeding rates were 50 lbs/acre (54.6 kg/ha) and wood fiber mulch rate was 2,000 lbs/acre (2182 kg/ha). Seed was broadcast prior to mulching. The different lime and fertilizer rates were based on soil needs as determined by soil tests. Plots 6 and 7 were fertilized at standard recommended rates. Plot 7 was not seeded.

Table IV-5. Treatments applied to the highway slope on I-80

Plot Number	Plot Size (feet)	Site Preparation	Soil Amendment	Fertilizer Type and Rate	Date Treated
1	20 x 80	Control	Control	Control	Oct. '80
2	20 x 45	Top 2" of soil loosened	3.5 tons/ac lime raked into top 2" of soil	16-16-16 700lbs/ac	Oct. '80
3	20 x 36	Control	Control	Control	Oct. '80
4	20 x 46	Top 2" of soil loosened	4.1 tons/ac lime raked into top 2" of soil	16-16-16 850 lbs/ac	Oct. '81
5	15 x 29	None	None	16-16-16 850 lbs/ac	Oct. '81
6	20 x 20	None	None	16-20-0 500 lbs/ac	Oct. '81
7	20 x 55	None	None	16-20-0 500 lbs/ac	Oct. '80
8	20 x 10	Top 4" of soil loosened	6.3 tons/ac lime raked into top 4" of soil	16-16-16 850 lbs/ac	Oct. '80

Note: To convert feet to meters, divide by 3.28. To convert inches to cm, multiply by 2.54. To convert, U.S. tons to metric tons multiply by 0.91.

The seeding mixture used on I-80 appears in Table IV-6.

Table IV-6. Plant species seeded in trials on I-80

Species	Percent of Mixture	Pounds/Acre
'Zorro' annual fescue	50	25
'Blando' brome	34	17
'Berber' orchardgrass	8	4
Rose clover	8	4

Results and species adaptation. Due to the low pH of the planting site, grasses responded significantly to the presence of lime. 'Zorro' annual fescue was more tolerant of low pH values than either 'Blando' brome or 'Berber' orchardgrass.

In 1981, 'Blando' and 'Zorro' were well represented in limed plot 4. There was only a trace of 'Berber'. Cover was fair to good; no vegetation was present in adjacent nontreated areas. Limed plot 2 also had a good cover of seeded 'Blando' and 'Zorro' with a fair amount of volunteer ripgut brome. Plot 2, however, had been overtopped with a trace of topsoil.

During the second year (1982) the annual grass growth and vigor had dropped off significantly. This decreased competition allowed 'Berber' orchardgrass and rose clover to increase. The responses were most obvious in the limed plots. Plot 8 contained a higher percentage of 'Berber' orchardgrass than the other treated plots. This was probably due to the greater lime rate, which resulted in a higher pH level. The two control plots had no vegetation and the plot treated with 16-20-0 fertilizer had only a trace of herbaceous cover.

36. 'Zorro' annual fescue dominated the mixture seeded on a low pH site on I-80 north of Vallejo.

A good stand of 'Zorro' annual fescue was present during the second year in Plot 7 which had only been fertilized with 16-20-0. Apparently no seed was present in 1980 when the fertilizer was first applied. However, in the second year seed from adjacent plots had blown in, germinated, and taken advantage of the fertilizer remaining from the previous year.

In 1981, two plots were seeded with the same mixture as in 1980. One plot was fertilized with 16-16-16 at a rate of 850 lbs/acre (927 kg/ha) and the second was fertilized with 16-20-0 at a rate of 500 lbs/acre (546 kg/ha). Both plots were mulched with wood fiber at a rate of 2,000 lbs/acre (2182 kg/ha). First-year results (1982 evaluation) showed only a small percentage of 'Zorro' present.

Evaluations made in the fall of 1982 show that 'Berber' had increased in lime plot 2. 'Zorro' had also moved into areas where it had not been the year before. Small cracks in the rock had filled with soil, providing a medium for 'Zorro' to grow. 'Zorro' was less vigorous than in 1980 and 1981, and, because it was less competitive, 'Berber' had increased in density.

The only other plot to show any significant change was plot 7. This plot had been fertilized with 16-20-0 in 1980 but not seeded. The 'Zorro' stand which developed in the second year had increased in density during the fall of 1982. As in plot 2, soil caught around the base of old plants and in rock cracks. These areas were not covered by any vegetation in 1980 and 1981 but did support plants in the fall of 1982.

Plot 4, seeded, fertilized and limed in 1980, showed very little change from 1981 to 1982. 'Berber' had increased some around older parent plants. 'Blando' and rose clover decreased while 'Zorro' increased.

The 1981 seeded, fertilized and mulched plots (5 and 6) performed poorly. There was some 'Zorro' germination but cover was poor. Due to the location of plots 5 and 6 on the slope, seed and fertilizer were probably washed from the surface before plants could become established.

Conclusions and Recommendations

Results from studies on I-80 indicate that topsoil, lime, fertilizer and a seeding mix of 'Blando', 'Zorro', rose clover and 'Berber' would be the ideal method for revegetation and erosion control. However, this type of treatment is extremely expensive and far too costly for large areas. Evaluations show that less intensive measures can produce acceptable results.

Two plant characteristics that must be taken into account when revegetating these types of critical sites are ease of plant establishment and maintenance, and longevity of stand. To maintain a grass stand of mixed species the slope pH must be raised to nearly pH 7. The lime application greatly encouraged the establishment of 'Berber' orchardgrass and 'Blando' brome. 'Zorro' annual fescue performed well without the lime application. Data from two growing seasons indicate that stands of 'Berber' and 'Blando' could be expected to survive for several more seasons where lime had been part of the treatment. 'Zorro' annual fescue could be expected to maintain itself for several more years in the nonlimed areas. 'Zorro' can tolerate low pH conditions.

Slope stability is extremely important for plant establishment. A method must be employed to prevent soil movement until seedlings become established. Plots 5, 6 and 7 demonstrate well the importance of soil stability. Plots 5 and 6 were situated on the most erosive material on the slope. Seeds were probably washed away before they could germinate. Plot 7 was positioned where the slope material was comprised of stable fragmented rock. Seed had invaded from adjacent stands, remained, and germinated.

Two types of revegetative treatments can be recommended for critical sites such as this on I-80. The least intensive treatment would be to seed 'Zorro' annual fescue at 35 lbs/acre (38.2 kg/ha) and rose clover at 5 lbs/acre (5.5 kg/ha). Fertilizer could be applied at a rate of at least 2,000 lbs/acre (2182 kg/ha). If wood fiber mulch is not sufficient to prevent soil movement, straw at a rate of 4,000 lbs/acre (4364 kg/ha) should be used along with a tackifier. If a perennial grass, such as 'Berber' orchardgrass, is desired, a slightly more intensive treatment must be applied. Lime at a rate sufficient to raise the slope material to a level near pH 7 should be worked into the slope surface. The seeding mixture recommended in the next subsection for use on Highway 16 can be used. Fertilizer and mulch should be applied as discussed above.

STATE HIGHWAY 16 (LOW pH SOILS)

The planting on Highway 16 was also made in cooperation with the Caltrans Translab as part of its water quality study. The seed mixture used on Highway 16 was the same as that on I-80 (see Table IV-6).

Plots were established on a north facing cut slope. Slope material was described as poorly cemented sands and clays with pH values near 4.6. The slope is extremely erosive and was void of any vegetation prior to planting. The slope surface is very unstable, which makes plant establishment difficult.

Average annual precipitation is 20 inches (51.0 cm) per year. The dominant surrounding vegetation is chamise, whiteleaf manzanita, blue oak, scrub oak and annual grassland.

Direct Seedings

Methods of establishment. Four plots were established in the fall of 1980. One plot was covered with 4 to 6 inches (10.2-15.2 cm) of topsoil. A 4.2 tons/acre (3.8 metric ton) rate of lime was worked into the top 3 inches (7.6 cm) of soil in plot 2. The third plot was left untreated as a control and plot 6 was treated only with 16-20-0 fertilizer. No mulch or seed was applied to plot 6 or to the control.

Two plots were established in 1981. The same seeding mix was used as in the previous year. Plot 4 was fertilized with 900 lbs/acre (982 kg/ha) of 16-16-16 fertilizer and plot 5 with 500 lbs/acre (546 kg/ha) of 16-20-0.

Seeding rates were 50 lbs/acre (55 kg/ha) and wood fiber mulch rates were 2,000 lbs/acre (2182 kg/ha). Seed was broadcast prior to mulching. Plots varied in size according to their position on the slope. Fertilizer and lime rates were adjusted to correct soil deficiencies. Plots 5 and 6 were fertilized using standard recommended rates. Table IV-6 shows the treatments applied to these six plots.

37. 'Berber' orchardgrass produced low, dense covers in plots on an erosive road slope along Highway 16. Caltrans Translab personnel applied lime to one plot and topsoil to a second.

Table IV-7. Treatments applied to slopes on Highway 16

Plot Number	Plot Size (feet)	Site Preparation	Soil Amendment	Fertilizer Type and Rate	Date Treated
1	20 x 26	Loosen top 3" of soil	4-6" of top-soil compacted by foot	16-16-16	Oct. '80
2	20 x 30	Loosen top 3" of soil	4.2 ton/acre lime raked into top 3" of soil	16-16-16 900 lbs/ac	Oct. '80
3	20 x 34	Control	Control	Control	Oct. '80
4	10 x 43	None	None	16-16-16 900 lbs/ac	Oct. '81
5	10 x 47	None	None	16-20-0	Oct. '81
6	20 x 30	None	None	16-20-0 500 lbs/ac	Oct. '80

Note: To convert feet to meters, divide by 3.28; inches to cm, multiply by 2.54; U.S. tons to metric tons, multiply by 0.91.

Results and species adaptation. Both the lime and topsoil plots established in 1980 provided very effective erosion control during the first year. The fertilized but unseeded plot did not give enough cover to adequately check erosion.

Early season cover in the lime plot was rather sparse. Seeded annual grasses did not show early vigorous growth as they did on the adjacent topsoil plots. The lack of annual grass competition worked in favor of the perennial 'Berber' orchardgrass. 'Berber' was denser within the lime plot.

Annual grass growth was vigorous within the topsoil plot. An early dense cover of annuals provided good early erosion control but did suppress the growth of 'Berber'.

Second year (1982) results showed decreased annual grass growth in both the lime and topsoil plots. Apparently, much of the fertilizer had been exhausted. The depressed annual grass growth definitely benefited 'Berber' orchardgrass. Rose clover had also increased in the topsoil plot during the second year.

Since 'Berber' orchardgrass is an early growing, vigorous perennial grass, it was able to take advantage of the sparse conditions originally present in the lime plot. 'Berber' seedlings were dense in the second year.

Depressed growth of annual grasses also encouraged perennial grass growth. The same type of response was observed in the topsoil plot but the density of 'Berber' was less due to the heavier growth of of annual grasses during the first year.

Plots 4 and 5, established in 1981 without the benefit of soil preparation or amendments, produced good stands of 'Zorro' annual fescue. 'Zorro', an invasive annual grass, is well adapted to critical situations like these on Highway 16. 'Blando' brome requires a little better environment and seedbed for optimum growth.

Conclusions and Recommendations

Herbaceous cover can most effectively be achieved by seeding after a 4- to 6-inch (10.2-15.2 cm) layer of topsoil is applied to the surface of slopes composed of erosive and sterile materials. This method, however, is laborious, and usually prohibitively expensive.

Sites comprised of material like the cut slopes on Highway 16 are basically unstable. Seed can often be washed away before it has an opportunity to germinate. If revegetation is to be achieved, these types of slopes must be stabilized. Topsoil and lime applications have provided stability to such slopes, but both treatments are too intensive for routine use.

Results from the Highway 16 studies show that an invasive annual grass such as 'Zorro' annual fescue will germinate quickly after the first fall rains. Plant species that provide vigorous early growth can often check the erosion that would occur if only a late maturing species were used.

Studies also show that fertilizer must be applied to these critical sites every few years if stands of annual grasses are to be maintained. The use of a perennial grass such as 'Berber' orchardgrass may relieve this maintenance somewhat. 'Berber' performed better in succeeding years after annual grass growth had decreased. It became well established when the seeded annuals were less dense. 'Berber' is actually a preferred cover since it remains green into the summer months.

From plot evaluations on Highway 16 it appears that an effective and inexpensive erosion control seed mixture could be:

Species	Percent of Mixture	Poundss/Acre (kg/ha)
'Blando' brome	10	5 (5.5)
'Zorro' annual fescue	10	5 (5.5
'Berber' orchardgrass	60	30 (33)
Rose clover	20	10 (11)

'Blando' brome and 'Zorro' annual fescue would provide the rapid initial cover necessary for soil stabilization. A low seeding rate for 'Blando' and 'Zorro' would give 'Berber' orchardgrass an opportunity to become established and provide the long-term cover desired. Rose clover would also benefit from the low seeding rate of annual grasses since it is adapted to poor sites with little herbaceous competition. Rose clover can add color and fertility to the slope.

U.S. BORAX (HIGH BORON SOILS)

Personnel at the United States Borax and Chemical Corporation, Boron, CA were very helpful in making a portion of their stockpile area for plant testing. The planting was located on a level site where the soil material was comprised of clayey sand with a boron content of 20 ppm. Usually, soils which have a boron content over 2 ppm are considered detrimental to agricultural crops. It would have been desirable to test plants against different boron concentrations but in this case it was not possible, since most stockpiles are continually being overtapped with new material. This site was to remain unchanged for several years.

Average annual precipitation is 7 inches (18 cm). Indigenous vegetation is sparse but there are some plants of spiny saltbush and Russian thistle.

Container Plantings

Methods of establishment. Both gallon can and book binder stock were planted. Plants were propagated and raised at the Antelope Valley RCD nursery in Lancaster, CA. A standard 3-inch diameter (7.6 cm) soil auger was used to dig holes for book binder stock and a 4.5-inch diameter (11.4 cm) bucket type posthole digger for the gallon can material. Two ounces (57 grams) of Mag Amp fertilizer were applied with the backfill at the time of planting.

Eight shrub species were planted in January, 1980. Fifty percent of the plants of each species were irrigated with one gallon (4.0 liters) of water in June and July of the same year. There were no additional irrigations.

Results and species adaptation. Several species showed early effects from the high boron content of the growing medium. By July of 1980, wolfberry and rabbitbrush showed burning of the leaves. Sixty percent of the silver sage were dead and all big sagebrush plants were stunted. The three species of saltbushes, however, showed excellent growth and vigor. 'Marana' fourwing saltbush, 'Casa' quailbush and desert saltbush showed no ill effects from the boron. All three species showed excellent growth. Even though spiny saltbush was not available for planting, it should do well, since native plants are growing in the immediate vicinity of the test plots.

38. Desert saltbush, 'Marana' fourwing saltbush and 'Casa' quailbush showed little effects from the high boron soil near Boron.

U.S. HIGHWAY 395 NORTH OF BISHOP (VOLCANIC TUFF SOILS)

This planting site is situated at an elevation of 6,000 feet (1835 m) where material had been removed for highway construction. The soil material is Bishop tuff and is of volcanic origin. The soil has developed little and is uniform to a depth of about six feet (1.8 m). It is sterile, droughty, and light in weight. Pumice will float during heavy rains and blow away when dry. The volcanic tuff covers a large geographic area and many miles of highways run through it.

Average annual precipitation is 11 inches (28 cm) and comes in the form of rain and snow. The dominant surrounding vegetation is fourwing saltbush, big sagebrush, rabbitbrush, blackbrush and pinyon pine.

Direct Seedings

Methods of establishment. Direct seedings were made in four consecutive years. A slightly different method was used each year; however, all methods were standard. During the fall of 1978, 13 grasses and 11 shrubs were hand seeded at a rate of 20 lbs/acre (21.8 kg/ha) into 10 x 20' (3 x 6.1 m) plots. Wood fiber mulch at a rate of 2,000 lbs/acre (2182 kg/ha) was applied over the seed; 16-20-0 fertilizer at 250 lbs/acre (273 kg/ha) was included in the mulch slurry.

In the fall of 1979, 22 grass and 14 shrub species were again seeded at a rate of 20 lbs/acre (22 kg/ha) into 20 x 20' (6.1 x 6.1 m) plots. 16-20-0 fertilizer at a rate of 250 lbs/acre (273 kg/ha) was applied by hand after seeding. Straw at a rate of 4,000 lbs/acre (4364 kg/ha) was blown onto the seeded plots and covered with 750 lbs/acre (818 kg/ha) of wood fiber to act as a binder.

Straw and a paper mulch product were used as the mulch and binder in the 1980 seedings. To simulate drilling, a large rake-like tool was used to create furrows in the seedbed. Seed and fertilizer at the rates described above were applied directly into the furrows. The seedbed was then raked and strawed. Astromulch at 750 lbs/acre (818 kg/ha) was applied over the straw to act as a binder. Twenty-two grasses and 14 shrubs were seeded.

No large-scale seedings were made in 1981. Five grass species, two perennials and three annuals, were planted in a depth of seeding trial (Table IV-8). Each species was seeded at three depths: 0.75, 2 and 4 inches (1.9, 5.1 and 10.2 cm). Mag Amp fertilizer at a rate of 500 lbs/acre (546 kg/ha) was applied to each furrow at the time of seeding. In a separate trial, two rates, 500 and 1,000 lbs/acre (546 and 1091 kg/ha), of Mag Amp fertilizer were applied to existing stands of crested wheatgrass.

Results and species adaptation. Poor results were observed in all seeded plots. Some 'Blando' brome and red brome had emerged in the 1979 seeding but did not persist. Crested wheatgrass was also observed but one cannot be sure whether it was the seeded variety or a response to fertilizer by crested wheatgrass already present from a prior Caltrans seeding. The extremely low moisture-holding capacity of the volcanic tuff is at least partially responsible for the failures. As seen from the depth of seeding trials, 'Luna' pubescent wheatgrass, 'Largo' tall wheatgrass and 'Blando' brome grew quite well from the 2-inch (5.1 cm) seeding depth. All three of

these species produced strong and vigorous seedlings. Seed was able to take advantage of deeper moisture, germinate and push through several inches of drier soil.

Table IV-8. Depth of seeding trial on volcanic tuff north of Bishop

Species	Depth of Seeding (inches)*	Emergence Yes(Y) No(N)	Rating**
Luna	3/4	Y	F-G
	2	Y	G
	4	Y	P
Largo	3/4	Y	F-G
	2	Y	G
	4	Y	P
Red brome	3/4	Y	P
	2	N	-
	4	N	-
Blando brome	3/4	Y	F-G
	2	Y	G
	4	N	-
Zorro	3/4	Y	F
	2	N	-
	4	N	-

* To convert inches to cm, multiply by 2.54.
** G - Good, F - Fair, P - Poor

It was hoped that seeded annual grasses could produce stands for one year. Even though they would not persist, the residue could provide the conditions needed for indigenous species to invade. However, the response from annual species was not good enough to recommend such a procedure.

39. Shrub survival was high but growth was slow on the volcanic tuff north of Bishop.

Of all grass species tested on the site only 'Luna' pubescent wheatgrass and crested wheatgrass produced favorable results. No seeded woody plants became established. Numerous rabbitbrush plants have invaded the test area.

Container Plantings

Methods of establishment. Plants from local and nonlocal sources were planted as book binder and gallon can stock. The same planting procedures were used as those described earlier. Rodent protecters were used even though several nearby Caltrans plantings established a few years before experienced little browsing.

All shrubs were given one gallon (4.0 liters) of water at the time of planting. Several plants of each accession were then irrigated monthly from April through October with one gallon (4.0 liters) of water each. Basins were constructed around plants scheduled for irrigation and water was then applied by hand from a bucket. The same irrigation procedures were used as those described for the Ridgecrest planting.

Results and species adaptation. Survival of most container plantings was good. Growth, however, was slow, probably due to the sterile soil material. The type and size of container had little effect on plant growth or survival. Success depended more on the plant species used than on the treatment employed. Shrub and tree species indigenous to the area performed better than nonnatives originating from similar climates.

40. 'Marana' fourwing saltbush (left) and rubber rabbitbrush were two of the most vigorous shrubs on volcanic tuff material.

Container plants of grasses were planted at this site as had been done on U.S. 395 near Ridgecrest, CA. Survival and growth again were not good enough to recommend this planting procedure for herbaceous cover along the desert highways.

41. Desert peach (left) and big sagebrush (right) are two native shrubs that show promise on volcanic tuff soil material.

Since only a few plants of each accession were planted, observations were mostly subjective and numerical data had to be interpreted with these limitations in mind. A few of the many factors that can influence plant performance are the size and conditions of plants when established, their position on the slope, the damage caused by rodents to roots and foliage, and the effects of wind-blown sand.

Irrigation seemed to aid the survival of only a few shrub species. Within the 1980 planting, bladdersenna, Nevada ephedra and green ephedra responded to supplemental irrigation. Of the shrubs planted in 1981, irrigated plants of 'Wytana' fourwing saltbush and desert broom survived, whereas non-irrigated plants died.

In the spring of 1982 a severe cold period set in just after planting. Most of the woody plants were severely hurt. 'Marana' fourwing saltbush, blackbrush, Apache plume and single-leaved pine, however, did survive. Within this 1982 planting no significant differences were observed between irrigated and nonirrigated plants.

Of all the woody plants tested, ten native and three nonnative species can be recommended for use on this type of site. It can be speculated that these species would also perform well on other sites within this climate zone. These better performing plants are listed on Table IV-9.

Table IV-9. Native and nonnative woody plants that performed best on volcanic tuff north of Bishop

Native Species	Nonnative Species
Big sagebrush	Apache plume
Silver sagebrush	Prairie sage
Fourwing saltbush	Desert saltbush
Rabbitbrush	
Blackbrush	
Cliffrose	
Nevada ephedra	
Pinyon pine	
Desert peach	

U.S. HIGHWAY 395 (LITTLE LAKE, 105 MILES SOUTH OF BISHOP) - DECOMPOSED GRANITE SOIL

Soils derived from decomposed granites are probably the most common 'problem soils' encountered by Caltrans. These soils are also some of the most difficult to revegetate. Usually, the planting medium is not a developed soil, but rather consists of fragmented, porous parent material.

The road slope on which these plots are located is a representative decomposed granite cut slope. The slope is east facing and the pH of the soil material ranges from 7.5 to 8.

Average annual precipitation is 7.5 inches (19 cm). The dominant surrounding vegetation is rubber rabbitbrush, creosote bush, and desert saltbush.

Direct Seedings

Methods of establishment. Direct seedings of 21 grasses, 16 shrubs and 1 forb were made in the fall of 1979 and 1980.

The establishment techniques used each year were the same. Seed at a rate of 20 lbs/acre (22 kg/ha) was drilled into 10 x 20' (3.0 x 6.1 cm) plots. 16-20-0 fertilizer at a rate of 250 lbs/acre (273 kg/ha) was applied by hand. Plots were mulched with 4,000 lbs/acre (4364 kg/ha) of straw and covered with 750 lbs/acre (818 kg/ha) of Astromulch to act as a binder. The same species and varieties were seeded both years.

42. Red brome (top, center of plots) was the only grass species that developed a good cover on decomposed granite near Little Lake. Indigenous Arabian grass responded to fertilizer and occupied most of the plots.

Results and species adaptation. Of all the herbaceous plants seeded, only three annual grasses germinated. These were 'Blando' brome, 'Zorro' annual fescue and red brome. Only red brome persisted for more than one year. Woody plants seem to be better adapted to harsh roadside conditions in the desert environments than are herbaceous species.

Since natural wildlife food plant production is directly related to the amount of precipitation, seeded plant materials suffer less wildlife damage during years of good precipitation. 1980 was a below-normal rainfall year. Only one seeded shrub species was observed growing. Woody plants may not germinate in poor rainfall years, but, if they do, rodents usually browse the new seedlings as soon as they emerge. 1979 was an above-normal rainfall year. Six of the 16 woody species seeded germinated and were alive in 1983. The amount of available wildlife food and the subsequent depredation of planted species may account for differences in plant establishment during 1979 and 1980. Shrubs that were successful in direct seedings are listed in Table IV-10.

Table IV-10. Shrubs growing from seeded plots on decomposed granite along U.S. 395 near Little Lake

Species	Average Number of Plants Growing in 10x20' (3x6 meter) Plots in 1983
Big sagebrush	4
Desert encelia	3
Fourwing saltbush	3
Bladderpod	3
California buckwheat	4
Desert saltbush	97

Big sagebrush was the largest of all seeded shrubs. It was probably the least affected by rodents. Desert encelia and California buckwheat flowered and set seed. Fourwing saltbush and bladderpod were stunted due to continual browsing. Desert saltbush was the most vigorous of the seeded shrubs. It germinated in both 1979 and 1980 and was browsed heavily, but withstood rodent damage well.

43. Big sagebrush grew from seed to a height of about 4 feet (1.2 m) in three years.

A recommended seeding mixture for use under conditions similar to those at Little Lake is shown in Table IV-11. Two tons/acre (1.96 metric tons/ha) of straw and 250 lbs/acre (273 kg/ha) of 16-20-0 fertilizer should accompany the seed. A straw binder is necessary since straw would otherwise be blown away. Wood fiber at a rate of 750 lbs/acre (818 kg/ha) applied over the straw has proven satisfactory.

Table IV-11. Recommended shrub species and seeding rates for use on highway slopes similar to those at the Little Lake planting site

Species	Pounds/Acre (kg/ha)	Percent of Seeding Mixture
Big sagebrush	5 (5.5)	10
Desert encelia	10 (11)	20
Fourwing saltbush	15 (16.5)	30
California buckwheat	5 (5.5)	10
Desert saltbush	15 (16.5)	30
	50 (55)	100

Container Plantings

Methods of establishment. The same planting procedures and irrigation schedule as described in Section III for the Ridgecrest site were followed for this planting. Many of the plant species used were the same as those planted on the volcanic tuff north of Bishop.

Results and species adaptation. As at the Bishop site, the grasses performed only marginally. The native desert needlegrass survived without irrigation but did not grow adequately to warrant planting from containers. 'Paloma' Indian ricegrass and smilo grew well and set seed. Container plants of Indian ricegrass have been planted by others for use as a seed source (8). The establishment of Indian ricegrass stands by using container plants may have possibilities. No natural increase was observed from these trials.

From the beginning of the study rodents were a constant threat to plant survival. The planting made during the fall of 1979 was completely eliminated by rabbits. Rodent protectors were used around all shrubs in subsequent plantings. Individual plants were damaged within these protected plantings but some shrubs of most accessions survived and grew. Without protection, plant performance could not have been observed.

44. The saltbushes, primarily desert saltbush, were the better performing shrub species on decomposed granite near Little Lake.

In general, survival and growth of indigenous shrub species were good. Irrigation schedules were carefully adhered to; however, irrigation had little effect on survival. There were differences between the irrigated and nonirrigated plants within an accession, but since so few plants of each accession were planted, mortality was usually attributed to something other than the lack of irrigation. Irrigation increased height and width of desert broom but not survival.

45. Desert broom (left) is an attractive shrub that responded to irrigation. Smilo (right) produced abundant growth when planted as container stock.

In some cases height and width figures may be deceiving in that rodents kept shrubs trimmed to the size of the protection device, 15 inches high and 3 inches in diameter (38 cm x 7.6 cm). Generally, the more palatable species, such as the saltbushes, were affected most. In the case of the shadscale, the protectors were broken and the plants destroyed.

It was unfortunate that the greatest variety of plant species was not available until 1982. Only one year of performance data could be evaluated. In general, native species showed the most vigor and growth. The saltbushes are probably the best adapted of all species tested. Desert saltbush was planted each year. 'Marana' fourwing saltbush was planted in two consecutive years. These two species are probably best suited for use in revegetation.

CONCLUSIONS

A problem soil as defined in this study is one that is difficult to vegetate due to its structure or some toxic substance or element. Serpentine soils are probably the most difficult soils to vegetate. A number of investigators have studied serpentine soils and their relationships to plant distribution (3,5,6,8,9,10,11,12). However, few actual attempts have been made to revegetate serpentine soils in the coastal mountains or Sierra Nevada foothills of California.

This study screened grass and shrub species in actual tests on serpentine soils. The main objective of the study was to evaluate plant species and not to alter planting medium. Roadslopes comprised of serpentine soils

usually present four different types of plant materials problems: 1) droughtiness; 2) low fertility; 3) high magnesium-to-calcium ratios; and 4) toxic levels of one or more heavy metals. The planting sites on State Highways 49 and 124 were primarily concerned with the first three problems.

Two perennial grasses, 'Luna' pubescent wheatgrass and 'Largo' tall wheatgrass, emerged from seed. These species grew where the serpentine soils had been covered with topsoil. 'Zorro' annual fescue, 'Blando' brome and 'Wimmera 62' ryegrass produced excellent stands during their first year of growth, but stands deteriorated in subsequent years as fertility decreased. California buckwheat was the only seeded species to survive.

Successful species planted as container or balled stock were Oldman saltbush, California buckwheat, digger pine, Ponderosa pine, Jeffrey pine, Coulter pine, serpentine manzanita and Sargents cypress. 'Largo' tall wheatgrass and 'Berber' orchardgrass also performed well as container stock.

The best perennial plants on these serpentine soils were hardy and drought tolerant. They withstood high magnesium levels but their growth was slow. Pines put on little height growth but good lateral growth.

On the low pH soil on I-80 north of Vallejo, a mixture of 'Berber' orchardgrass, 'Zorro' annual fescue and rose clover was successful in plots that had been treated with lime. In plots that were not limed, 'Zorro' produced acceptable erosion control covers. On a sandy, unstable cut slope on State Highway 16, 'Berber' orchardgrass proved that it is one of the best perennial grasses for use on critically eroded sites in the coastal mountains and Sierra Nevada foothills of California.

Eight shrub species were planted from containers on a high boron soil near Boron. 'Marana' fourwing saltbush, 'Casa' quailbush and desert saltbush performed very well. Big sagebrush, wolfberry, silver sage and rabbitbrush were severely stunted or killed by the high concentrations of boron.

The volcanic tuff north of Bishop, California on U.S. 395 is a sterile, droughty soil. No seeded species performed well. 'Luna' pubescent wheatgrass and crested wheatgrass did emerge and produce stands. 'Blando' brome and red brome germinated but did not persist beyond the first year. Survival among woody container plants was high but growth of most species was slow. 'Marana' fourwing saltbush, big sagebrush, rubber rabbitbrush, desert peach, Apache plumes, pinyon pine, Nevada ephedra and green ephedra were the better performing woody plants.

Both container plantings and direct seedings were made on a decomposed granite soil near Little Lake. Red brome was the only seeded herbaceous species to establish a stand that persisted for more than one year. 'Blando' brome and 'Zorro' annual fescue grew only in the first year. Six shrub species germinated, five of which were growing well after three years. These were desert saltbush, 'Marana' fourwing saltbush, desert encelia, California buckwheat and big sagebrush. Bladderpod germinated but grew poorly. Bursage, 'Marana' fourwing saltbush, big sagebrush, shadscale, 'Casa' quailbush and oldman saltbush were the most outstanding woody plants established from containers.

V EVALUATIONS OF PLANTINGS MADE BETWEEN 1970 AND 1975

Approximately 2,000 plots of grasses, legumes and shrubs were planted along California highways (and western Nevada highways within the Tahoe Basin) between 1970 and 1975. These plantings were established as part of a Caltrans-SCS cooperative revegetative study. The purpose was to search for drought-tolerant plant materials for erosion control, revegetation, and landscaping. A report summarizing the five-year results was published in June, 1976 (1). As part of the present study, these plantings were evaluated each year from 1978 through 1982. Evaluations were made three times a year in 1978 and 1979 and once a year from 1980 through 1982.

METHODS OF EVALUATION

Each individual plot established during the 1970-75 study was evaluated. Performance ratings were assigned to each plant species or seeded plot. Visual observations were made for persistence, erosion control, fuel volume, appearance, maintenance and ecological succession.

Findings were noted in the form of ratings from 1 to 9 or 1 to 3 accompanied by remarks on ecological succession. Persistence ratings were on a scale from 1 to 9: 1-2 was excellent; 3-4 good; 5-6 fair; 7-8 poor; and 9 indicated no plants were present. These numbers were also used to rate the amount of soil covered by seeded plants, plant litter, invading species and bare soil. Fuel volume for herbaceous species was rated 1 light, 2 medium, and 3 dense. Woody plant fuel volume was rated 1 light, 2 medium and 3 high. Appearance was rated 1 good, 2 fair and 3 poor. Maintenance was rated from 1 to 3 depending upon the amount of care expected to be required to maintain the desired plant species.

This section summarizes results obtained with the aid of the rating system. Observations were subjective and depended upon the experience and judgment of the evaluator, who has spent over 25 years testing and evaluating plants for erosion control.

OBSERVATIONS AND RECOMMENDATIONS

NORTH-CENTRAL COASTAL AND SIERRA NEVADA FOOTHILLS

Annual Grasses and Legumes.

Results from evaluations of annual grass and legume seedings were often confusing. Planted species have spread outside the areas in which they were originally seeded. They have mixed in various proportions among themselves and with resident annuals such as wild oats, ripgut brome and yellow star thistle. In some areas, native lupines invaded seeded areas and produced showy flowers. The mixing of annuals seemed to be greater in older stands and in plots adjacent to grassy areas. Whether the seeded annuals held in place, spread, or mixed, the existing vegetative covers are adequate to control erosion.

Persistence. The most persistent annuals seeded were 'Zorro' annual fescue, red brome, 'Blando' brome, 'Lana' woollypod vetch, and rose clover. Only a few plants of poorly adapted species such as 'Cucamonga' brome and big quaking grass were found. Since foxtail fescue and soft chess are common indigenous grasses, there is always a question as to whether the plants found are progeny of the seeded grasses or resident plants. Red brome is not present naturally at many of the planting sites. 'Lana' woollypod vetch and rose clover are not abundant in seeded plots although they are common components of adjacent plant communities. Persistence ratings for the five species averaged good to fair since these species already make up a considerable proportion of the natural plant cover.

The present composition of species within plots originally seeded with a mixture of 'Zorro' annual fescue, rose clover, and California poppy gives an idea of how composition changes. At Penn Valley, on a steep west-facing cut surrounded by oak and shrubs, 66% of the soil is covered by plants. Annual fescue comprises 60% of the plant cover, rip-gut brome 5% and the California poppy 1%. Moss and litter make up 19% and bare ground 15% of the remaining area. On a southwest-facing cut at Crystal Springs, the proportions are 'Zorro' annual fescue 10%, rose clover 40%, wild oats 1%, California poppy a trace, Lana vetch 10%, litter 10%, and bare soil 29%. The present stand composition on a west facing fill at Crystal Springs is wild oats 20%, rip-gut brome 10%, annual sweet clover 20% , California poppy 1%, and miscellaneous indigenous annuals 49%. Nonseeded herbaceous species make up 69% of the plants now occupying this fill slope at Crystal Springs. Species composition within annual plant communities changes rapidly from year to year. After several years the more competitive indigenous annuals tend to dominate the site.

Erosion control. All annual grass covers were rated high for erosion control regardless of the species composition. Usually, herbaceous ground covers were 70% or more. If less than 70% cover, the ground was rocky and less erodible. Generally annual vegetation, whether seeded or indigenous, provides good erosion control cover.

Fuel volume. Plant covers of herbaceceous species provide less fuel than either brush or trees. Some herbaceous species are characteristically small and produce less fuel than others. 'Zorro' annual fescue, for example, was usually the shortest grass in a mixture and had the least amount of fuel. However, its stems are dense and fine and will carry fire. Rose clover is also short but the stems are coarse. Fire travels rapidly through wild oats since stems are tall, thin, and dense and the seed heads possess thin papery glumes.

46. Several shrub species are growing well near Penn Valley nine years after planting.

Appearance. Plots of seeded grasses and legumes are similar in appearance to the surrounding countryside where plant species are the same or similar. Little was done to improve seeded stands. Some areas were mowed to encourage California poppies.

Maintenance. Little maintenance was given to any of the seeded plots. It is impractical to perform maintenance on steep and rough slopes, except perhaps to fertilize. There are no ways to prevent annual grass species from mixing. It is not possible to sustain stand characteristics of California poppy. Mowing may reduce tall grasses and allow shorter ones to compete. Timing is a critical factor when attempting to alter mixed annual stands by mowing.

Ecological succession. Most annual grass seedings now consist of mixtures of seeded species and invading annuals and perennials. This may not be true succession but it is a step towards soil improvement. Stands of annual grasses are well established and perennial grasses are not competitive enough to displace them. The invasion by coyote brush into test plots at Crystal Springs, and of bush monkey flower and deer vetch into area outside the trials indicates succession from grasses to chaparral.

Perennial Grasses and Legumes

Persistence. Only four perennial grasses and one perennial legume have been persistent: Hardinggrass, 'Perla' koleagrass, 'Luna' pubescent wheatgrass, 'Palestine' orchardgrass and birdsfoot trefoil. There are good stands of Hardinggrass and 'Perla' koleagrass on cut and fill slopes on both north and south exposures. Survival on southern cut slopes depends upon a plant's ability to tap moisture from deep soil or to form fractures in parent material. 'Luna' pubescent wheatgrass and 'Palestine' orchard-

grass are mainly limited to cooler north-facing slopes. In the coastal area, birdsfoot trefoil persists on moist slopes and along the highway edge where water concentrates. There are few trefoil plants on dry slopes. Perennial grasses did not spread from seed as did the annuals. Rhizomatous species such as 'Luna' pubescent wheatgrass spread slowly underground.

47. Most grass plots near Crystal Springs have lost their identity and are occupied by indigenous vegetation.

Erosion control. Good perennial stands provide effective erosion control. Most of the poorer perennial stands have been invaded by annuals so that a good cover still exists. Some erosion was observed around clumps of perennial ryegrass seeded on a sandy soil at Watsonville.

Fuel volume. 'Luna' pubescent wheatgrass and 'Palestine' orchardgrass produce less fuel than either the taller growing Hardinggrass or 'Perla' koleagrass. Summer evaluations show that perennials stay green longer than annuals. A long green period is important for fire control.

Appearance. Hardinggrass and 'Perla' koleagrass seedings developed into tall and uneven stands. 'Palestine' orchardgrass plants become stemmy at maturity whereas 'Luna' pubescent wheatgrass produces short, even growth with few stems. Birdsfoot trefoil stays green much of the summer and has small but showy flowers.

Maintenance. There was evidence at Ione that fertilization increases the density of perennial grass stands. Fertilization kept the number of annuals to a minimum.

Ecological succession. Where 50% or more of the soil is covered by perennial grass there is little invasion by other plant species. Near Watsonville where 'Luna' pubescent wheatgrass made up only 20% of the cover, other species such as rose clover, California poppy, native trefoil, foxtail fescue, hairgrass and Monterey pine have invaded.

Shrub evaluations from 1978 to 1982 were more definitive than those made in 1975, since plants were nearing maturity. Generally, shrubs have persisted well. However, the slow mortality of established plants shows that planted shrubs die over a period of years and are not necessarily replaced by resident shrubs. Some species such as buckbrush ceanothus are probably shorter lived.

Shrub Species

Shrubs planted in foothill areas have done well. However, attempts to grow shrubs in these areas can be risky. Shrubs can be damaged or killed for several reasons, and these factors should be considered before planning any shrub planting.

Persistence. Thirteen of the 60 shrub species tested in the foothills survive and show potential. Eight of these are growing well in both foothill areas; three have been selected for use only in the Coastal Foothills and four show promise in the Sierra Nevada Foothills. In 1975 nine species were listed as promising for use in both foothill areas. Others were too young to evaluate. The listings of preferred species in 1975 and 1982 are shown in Tables V-1 and V-2.

Table V-1. Woody plant species rated high in 1975 and 1982 for erosion control and revegetation in the North-Central Coastal Foothills and the Sierra Nevada Foothills (species listed in order of preference)

1975	1982
Coyote brush	Coyote brush
Fourwing saltbush	Buckbrush ceanothus
Rockrose	Creeping sage
California buckwheat	California buckwheat
Whiteleaf manzanita	Fourwing saltbush
Buckbrush ceanothus	Rockrose
Quailbush	Quailbush
Oleander	Wartleaf ceanothus
Wartleaf ceanothus	

Overall, the shrubs did persist well; however, mortality figures for six shrub species growing at Crystal Spring show a 15% loss from 1975 to 1982. If this rate were to continue, all the shrubs would be dead in about 25 years. This figure may be high for some short-lived species. Rockrose, bush monkey flower, and California buckwheat reproduced voluntarily from seed.

48. California buckwheat is one of the best shrubs for erosion control in the Coastal and Sierra Nevada Foothills. Both direct seedings and container plantings have performed well.

Table V-2. Woody plant species rated high for erosion control and revegetation in 1982 (shrubs listed are recommended for use only in the area specified)

North-Central Coastal Foothills	Sierra Nevada Foothills
Australian saltbush	Lemon ceanothus
Oleander	Ceanothus cuneatus x C. prostratus hybrid
Bush monkey flower	Dwarf flannel bush
	Bigberrry manzanita

Erosion control. Prostrate and other low-growing shrubs protect the soil from raindrop impact and dripping water more effectively than do tall shrubs. Low-growing plants also tend to reduce sheet erosion. Creeping sage, Australian saltbush and the Ceanothus cuneatus x C. prostratus hybrids are successful low-growing species. Tall spreading shrubs, such as California buckwheat and dwarf flannel bush, are better for erosion control than those that become 'leggy' such as coyote brush.

49. The buckbrush-squaw carpet hybrid has persisted well in all plantings. It has been used to a limited extent by Caltrans landscape personnel.

Fuel volume and fire control. Some factors that influence the spread of fire are: volume of fuel; moisture content of the fuel; density of leaves, twigs and branches; and the amount of oil in the fuel. Low-growing green covers such as creeping sage, Australian saltbush and the Ceanothus cuneatus x C. prostratus hybrid will not spead fire rapidly unless the heat is intense. Tall shrubs will carry fire more rapidly. California buckwheat is a fine-textured dense shrub that burns easily. Chamise, a tall species with fine leaves and twigs, contains oil and is quite flammable. Rosemary also contains oil and is combustible when the fuel moisture is low.

Appearance. Shrubs with large colorful flowers are more pleasing to the eye than those with obscure flowers. Well-rounded shrubs are more attractive than 'leggy ones'. Rockrose, wartleaf ceanothus, and dwarf flannel bush are three species that produce colorful flowers. Coyote brush and buckwheat lose their well-rounded form with age. Quailbush develops unattractive bare branches as it matures.

Maintenance. Except for plantings at Plymouth and Penn Valley, shrubs were given no care. Plants were irrigated at Plymouth and weeded at Penn Valley during the establishment period. These low maintenance regimes show that many shrub species will grow with little water if they are protected from grass competition, rodents, grasshoppers, deer and fire. Weeding is necessary to prevent aggressive herbaceous vegetation from crowding out low-growing and prostrate shrubs.

Ecological succession. The direction of ecological succession has been difficult to determine. As mentioned in the above paragraph on maintenance, weeding may be necessary to maintain some shrub plantings. Grasses and weeds will usually encroach upon the planted shrubs. In grassy areas, such as the Plymouth site, shrubs are in danger of being overwhelmed by invading grasses. At Crystal Springs planted shrubs are being invaded by volunteer seedlings of coyote brush. The native coyote brush will probably crowd out and eventually eliminate the planted shrubs.

Wildlife. Wildlife present two problems: 1) damage to planted material and 2) damage to moving vehicles. At Plymouth, all shrub species except the saltbushes were severely damaged by rodents and insects. Plants must be protected until they are old enough to resist wildlife depredation. This protection period could be from 5 to 10 years. It may be advisable in certain situations not to plant many plants of species that are attractive to wildlife. Buckbrush is a very promising shrub for revegetation but it is also a highly desirable browse plant. California buckwheat, black sage and rosemary attract honey bees. Plantings of these species could be made so that flight patterns of bees do not cross routes traveled by moving vehicles.

TAHOE BASIN AND VICINITY

Herbaceous Species

Perennial grasses and legumes. Of 46 grass and legume varieties seeded in the vicinity of the Tahoe Basin, six perennial grasses and one perennial legume are consistently better than all others. These are 'Luna' pubescent wheatgrass, 'Tegmar' intermediate wheatgrass, fairway crested wheatgrass, 'Latar' orchardgrass, 'Sherman' big bluegrass, 'Manchar' smooth brome and 'Lutana' cicer milkvetch. Two other perennial grasses, 'Potomac' orchardgrass and 'Oahe' intermediate wheatgrass, are promising. These and all other species that became established by 1975 are persisting. The stand ratings for 19 species have been outlined in Table V-3. Ratings for species seeded near Alturas have also been included.

Persistence. Establishment and persistence ratings in 1975 and from 1978 through 1982 were about the same for most grass and legume species. These ratings may change as plants adjust to difficult growing conditions on cut and fill slopes. Some stands have increased density through rhizome activity while others have improved by reseeding. 'Luna' pubescent wheatgrass, 'Tegmar' intermediate wheatgrass, western wheatgrass (the 727 strain), 'Sodar' streambank wheatgrass and 'Chemung' crownvetch have spread by rhizomes. 'Sherman' big bluegrass, milkvetch and 'Durar' hard fescue have spread by seed.

50. 'Luna' pubescent wheatgrass and 'Tegmar' intermediate wheatgrass are still the dominant species within mixtures seeded in the Tahoe Basin.

Table V-3. Stand Ratings in 1975 and 1982 for 19 Herbaceous Species tested in the Tahoe Basin and at Alturas*

Species	Establishment Rating * (1975) T	A	Stand Rating (1982) T	A	Erosion Control Rating ** T	A	Height	Color
Alfalfa, Rambler	P-F	P	P	NP	P	P	M	G
Bluegrass, 'Sherman' big	P-G	F-G	F	F	G	G	M	G
Brome, Manchar smooth	F	F	P	VP	-	-	M	LG
Crownvetch, 'Chemung'	P	NP	F	NP	-	-	M	G (flowers)
Fescue, 'Durar', hard	P-F	P-F	P-F	P-F	G	F	S	DG
Milkvetch, Cicer 'Lutana'	P	NP	P	NP	F	-	M	G
Orchardgrass, 'Potomac'	F	F	G	-	F	-	M	G
Sweetclover, yellow blossom	F	NP	VP	VP	NP	-	-	G (flowers)
Trefoil, 'Cascade'	P	NP	VP	VP	-	-	M	G
Wheatgrass, fairway crested	F-G	G-E	F	F	VG	VG	M	G
Wheatgrass, 'Greenar' intermediate	F	F	F	F	F	F	M-T	G-BG
Wheatgrass, 'Tegmar' intermediate	G	G	E	G	G	G	M	G
Wheatgrass, 'Luna' pubescent	G	G	E	G	G	G	M	G
Wheatgrass, 'Topar' pubescent	F	F	G	F	F	F		
Wheatgrass, 'Primar', slender	P	P	P-F	P-F	-	-		
Wheatgrass, 'Sodar' streambank	P	P	P	VP	P	-	S	BG
Wheatgrass, 'Alkar' tall	P	P	VP	P	-	-	T	G
Wheatgrass, 'Barton' western	P	P	P	VP	-	-	S	BG
Wheatgrass, 727 western	P	P	G	F	F	-	S	BG

* T= Tahoe Basin, A= Alturas;
P=poor, F=fair, G=good, NP=no plants, VP=very poor, VG=very good;
Height: S=low, M=medium, T=tall;
Color: G=green, LG=light green, DG=dark green, BG=blue green.

** Dash (-) means no rating

At the Lake Tahoe airport and Incline Village some plants of all seeded species died when soil erosion exposed plant crowns and roots to freezing temperatures. This happened on steep cut slopes during the wet 1977-1978 winter when there was little snow but much rain. In plots seeded to mixtures at the Lake Tahoe airport, the ratio of 'Sherman' big bluegrass to 'Luna' and 'Tegmar' shifted to favor 'Sherman' big bluegrass.

Below the control tower in a moist shady area, resident Kentucky and Canada bluegrasses partially replaced seeded species. Either the indigenous bluegrasses were better adapted or the seeded species were severely hurt by low temperatures.

'Potomac' orchardgrass and 'Oahe' intermediate wheatgrass have shown enough vigor and persistence to be considered major species for use. 'Potomac' orchardgrass is a vigorous strain of orchardgrass and would best be used in higher rainfall areas. The vigor of 'Oahe' intermediate wheatgrass approaches that of 'Luna' and 'Tegmar'; however, since 'Oahe' grows tall and robust it has been rated less desirable. Some plants of western wheatgrass showed strong and vigorous rhizome activity but few plants became established.

Erosion control. Any differences in soil erosion among stands of single species or mixtures were difficult to detect. There was less erosion in the seeded areas than in unseeded areas. More erosion was observed around bunchgrass plants than among the stems of rhizomateous grasses.

Fuel volume and fire control. Since perennial species remain green for long periods, they will not burn unless there is intense heat. Only in late summer and fall are perennials dry enough to carry fire rapidly. Plant species that dry early, such as 'Sherman' big bluegrass, are less desirable for fire control than later maturing species such as the intermediate wheatgrasses. Shorter grasses such as 'Durar' hard fescue do not carry fire as rapidly as taller species.

Appearance. Many people who deal with erosion control in the Tahoe Basin prefer the appearance of short plant species. They feel that grass looks unnatural in forested areas. Short varieties such as 'Durar' hard fescue are preferred over taller species such as 'Oahe' intermediate wheatgrass. Other people enjoy the unevenness of a mixture of tall and short varieties.

As grasses and legumes dry in late summer, residue accumulates on the soil surface. Dry stands of short grasses such as 'Durar' hard fescue, 'Sodar' streambank wheatgrass and 'Tegmar' intermediate wheatgrass are more attractive than 'Luna' pubescent or 'Oahe' intermediate wheatgrasses.

Maintenance. Most of the herbaceous plants tested are rugged drought-tolerant species that require little maintenance under natural conditions. On disturbed sites, however, plants often need nitrogen to develop normally. Where stands have deteriorated due to cold, drought or lack of fertility, the application of fertilizer has helped plant vigor. Some grass stands damaged by foot or vehicular traffic might be rejuvenated by applying fertilizer. In these situations fencing could be provided to protect damaged plants until they recover.

Ecological succession. Bare disturbed areas around the Lake Tahoe Basin have been improved indirectly by the seeding and fertilizing of test plots. Seeded species have often spread into adjacent nonseeded areas. Treated areas have also been invaded by resident plants that took advantage of mulch and fertilizer. Some of the more prominent indigenous plant species are native trefoil, buckwheat, cheatgrass, snowbrush, antelope bitterbrush, big sagebrush, lodgepole pine and Jeffrey pine.

Shrub Species

Forty-six varieties of native and introduced drought-tolerant shrubs were tested in the Tahoe Basin and vicinity. These shrubs were tested under dryland conditions on cut and fill slopes. The most promising species in 1976 and 1982 are listed in Table V-4.

Table V-4. Promising shrubs for use in revegetation in the Tahoe Basin (1976 and 1982 evaluations)*

1976	1982
'Bandera' Rocky mountain penstemon (N,P)	Dwarf arctic willow (N,P)
Caucasian sagebrush (N,P)	Slender arctic willow (N,P)
Bearmat manzanita (N,P)	Common lilac (N,P)
Prostrate summer cypress (N,P)	Sulphur flower buckwheat (P)
Dwarf arctic willow (N,P)	Mountain pride penstemon (P)
Slender arctic willow (N,P)	Squaw carpet ceanothus (P)
Common lilac (N,P)	Big sagebrush (SE)
Sulphur flower buckwheat (P)	Rubber rabbitbrush (SE)
Mountain pride penstemon (P)	Snowbrush (SE)
Squaw carpet ceanothus (P)	Antelope bitterbrush (E)
Big sagebrush ((SE)	Greenleaf manzanita (E)
Rubber rabbitbrush (SE)	Red osier dogwood (E)
Snowbrush (SE)	
Antelope bitterbrush (E)	
Greenleaf manzanita (E)	
Red osier dogwood (E)	

*N = Nonnative
P = Prostrate or low growing, less than 3' (3 m) in height
SE = Semierect, less than 5' (1.5 m) in height
E = Erect, 5' (1.5 m) or taller

In 1982 only three of the 7 nonnative species still looked promising. These were dwarf arctic willow, slender arctic willow, and lilac. Lilac is probably more useful for home gardening than for highway use. All nine native species looked good in 1982.

Persistence. Four of the seven introduced species are unacceptable for several reasons: 1) the dry flower stalks on 'Bandera' Rocky Mountain penstemon remain upright after flowering; 2) the centers of Caucasian sagebrush plants die out; 3) bearmat manzanita grows poorly; and 4) prostrate summer cypress plants are relatively short lived.

51. Bitterbrush has survived well in plantings in the Tahoe Basin. It is easily propagated from seed and could be used more often in plantings around the Tahoe Basin where deer browsing is light.

The most successful shrub trials are in the Northstar development. These plantings are within the conifer-shrub zone on dark soils derived from basalt and andecite. Average survival for 17 shrub species was 67% in 1975 and 60% in 1982. This gradual mortality is common. Survival of dwarf and arctic willow is 100%. Survival of big sagebrush, antelope bitterbrush, greenleaf manzanita, rubber rabbitbrush and mountain pride penstemon is high. Plantings of poorly adapted exotic shrubs such as 'Emerald Sea' juniper and prostrate summer cypress were failures. Survival from a 1973 spring planting of 150 squaw carpet ceanothus seedlings was 75% in 1975 and 35% in 1982. Unfortunately, squaw carpet ceanothus has a poor establishment record for such a vigorous growing native.

52. Greenleaf manzanita is growing well on some very harsh sites in the Tahoe Basin. It is a good intermediate size shrub for erosion control, aesthetics and general vegetation.

Erosion control. Short growing species planted at close intervals form good protective soil covers. Shrubs spaced far apart are less effective until roots become developed. Roots of tall shrubs usually reach to greater depths than those of low-growing shrubs.

Fuel volume and fire control. Tall shrubs produce more fuel and carry fire more readily than low-growing shrubs. Low-growing shrubs that should be considered for fire control are squaw carpet ceanothus, sulphur flower buckwheat and mountain pride penstemon. Big sagebrush and rubber rabbitbrush are intermediate in size but highly combustible. Stems are fine, dense and oily. Tall species such as greenleaf manzanita and tobacco brush ceanothus produce large amounts of fuel.

Appearance. The nine promising native shrubs and the two arctic willows blend well with the native landscape. Lilac can appear out of place when observed closely. Sulphur flower buckwheat and mountain pride penstemon produce colorful, attractive flowers.

Maintenance. Low-growing species require care to prevent tall shrubs from overtopping and crowding them out. Shrubs at higher elevations are not subjected to the annual grass competition that exists at lower elevations. Wildlife depredation is not a problem in the Tahoe Basin even though some buckbrush ceanothus plants were girdled by rodents near the Lake Tahoe airport.

Ecological succession. Native trees, shrubs, and herbaceous species have invaded many shrub plantings. Encroachment will probably continue as soils improve. Climax vegetation will eventually occupy the planting sites.

ALTURAS

Herbaceous and Shrub Species

Results obtained from plot evaluations near Alturas are similar to those for the Tahoe Basin. This is reasonable, since many of the same native plants are found in both areas. There is less precipitation at Alturas, but otherwise the climates are similar. The best grasses are 'Luna' pubescent wheatgrass, 'Tegmar' intermediate wheatgrass, 'Sherman' big bluegrass and 'Durar' hard fescue. All legumes failed due to limited precipitation. Most stands of western and 'Sodar' streambank wheatgrass failed. Where seeded grasses or legumes grew poorly, resident annuals, such as cheatgrass and mustard, took advantage of the fertilizer and developed fair covers for erosion control. Big sagebrush and rubber rabbitbrush invaded the seeded and fertilized areas.

Although no container-grown shrubs were planted at Alturas, direct seedings of bitterbrush and 'Wytana' fourwing saltbush emerged and persisted. Three plants of common bladdersenna, not previously reported, were observed in 1979. Seed had apparently germinated after lying dormant for several years. Most of the seeded shrubs had experienced severe browsing.

Bitterbrush, which is native to the Alturas area, is a good species for revegetation and landscaping. It is also an excellent browse plant and should not be planted in such abundance that it would attract wildlife to the highway.

There were many volunteer seedlings of big sagebrush and rubber rabbitbrush in the seeded plots. Few volunteers were observed in unseeded areas. Shrubs had taken advantage of the mulch and fertilizer applied during hydromulching operations. Protective vegetative covers of seeded species and volunteer cheatgrass also aided the invasion and establishment of native shrubs.

53. 'Luna' pubescent wheatgrass, 'Tegmar' intermediate wheatgrass and 'Sherman' big bluegrass provide effective erosion control south of Alturas 10 years after establishment.

CONCLUSIONS

Recent evaluations of seeded plots in the North-Central Coastal and Sierra Nevada Foothills showed that plantings of annual species, either in single species plots or mixtures, retained little evidence of their original composition. Indigenous annuals quickly mixed with seeded species. However, seeded annuals such as 'Blando' brome, 'Zorro' annual fescue and 'Lana' vetch will provide the needed erosion control during the first year following highway construction.

Only four perennial grasses and one perennial legume were observed growing from original plantings. Hardinggrass and 'Perla' Koleagrass were growing vigorously but they are too tall for most roadside plantings. 'Palestine' orchardgrass and 'Luna' pubescent wheatgrass survived on cool northern exposures. Their use should be restricted to deep soils on north exposures. Birdsfoot trefoil persisted where there was adequate moisture.

Eight woody species were doing well in both the North-Central and Sierra Nevada Foothills. These were: coyote brush, buckbrush ceanothus, creeping sage, fourwing saltbush, rockrose, quailbush, California buckwheat and wartleaf ceanothus. Australian saltbush, oleander, and bush monkey flower

performed well only in the North-Central Coastal Foothills. Lemon ceanothus, dwarf flannel bush, bigberry manzanita and the buckbrush ceanothus-squaw carpet ceanothus hybrid looked promising only in the Sierra Nevada Foothills.

Seven perennial grasses and one perennial legume performed well for over nine years in plots established in the Tahoe Basin. These were: 'Luna' pubescent wheatgrass, 'Tegmar' intermediate wheatgrass, fairway crested wheatgrass, 'Sherman' big bluegrass, 'Manchar' smooth brome, 'Oahe' intermediate wheatgrass, 'Potomac' orchardgrass and 'Lutana' cicer milkvetch.

'Luna' pubescent wheatgrass, 'Tegmar' intermediate wheatgrass, fairway crested wheatgrass, 'Sherman' big bluegrass, and 'Durar' hard fescue are the best of the perennial grasses planted near Alturas. No legumes survived in the Alturas plantings.

The most outstanding shrubs planted from containers in the Tahoe Basin were: dwarf arctic willow, slender arctic willow, sulphur flower buckwheat, mountain pride penstemon, squaw carpet ceanothus, big sagebrush, rubber rabbitbrush, snowbrush, antelope bitterbrush, greenleaf manzanita and red osier dogwood.

VI APPENDICES

APPENDIX A

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APPENDIX B

SEEDING GUIDE FOR CALIFORNIA

INTRODUCTION

This appendix is a revision of the seeding guide published in the 'Plant Materials Study' by George C. Edmunson, Jr. (1). Portions of the original recommendations have been changed to reflect more current evaluations of plant performance. In some cases, plant varieties and seeding rates are changed to coincide with standard SCS recommendations and current seed availability. Seeding rates are higher than those normally recommended for drilled seedings since critical area plantings are usually made under adverse growing conditions on poor seedbeds. Some recommendations are not based on soil series since most data were collected from plots established on parent materials. Some recommendations have been grouped according to average annual rainfall zones.

All recommendations are made in terms of Major Land Resource Areas (MLRA). Throughout each MLRA environmental conditions are similar, but differences occur in climatic, topographic, and soil conditions that produce variations in plant response. Resource areas are distinct units but separations often fall within the same climatic zone. Boundaries separating MLRAs are gradual. As a result, the same species are often recommended for use in more than one MLRA. Recommendations have been combined for MLRAs 14 through 18 and for Resource Areas 5 and 22.

Purity and germination figures were based on minimum seed certification requirements (when available). These standards should be followed to insure that good quality seed is used. Legume seed should always be inoculated before planting.

In the guide, botanical names are followed by varietal (Cultivar) names placed within single quotations and then common names in parenthesis.

MAJOR LAND RESOURCE AREAS California

MLRA-4. NORTHERN CALIFORNIA REDWOOD BELT

Major Land Resource Area 4 is found along the Pacific Coast from Jenner (Sonoma County) to the Oregon state line, in Santa Cruz County, and a small area in Monterey County. This is a humid area characterized by high average annual rainfall ranging from 32 to 80 inches; as a result, 68% of the land is forested. The dominant species are coastal redwood and Douglas fir. General elevations range from sea level to 2500 feet. The maximum extension inland is about 25 miles. Land forms vary from sand dunes to mountains. Because of favorable rainfall and other climatic factors, reproduction and revegetation take place readily. The soils are usually acid, which limits the growth of many plants. Severe erosion occurs on disturbed upland soils.

Perennial Mixture	Seeding Rate (pounds/acre)	Minimum Purity (percent)	Minimum Germination (percent)
Agropyron intermedium trichophorum*, 'Luna' pubescent wheatgrass	20	95	80
Dactylis glomerata 'Berber' (Berber orchardgrass)	15	85	80
Lotus corniculatus 'Kalo' (broadleaf trefoil)**	5	98	80
Optional			
Trifolium incarnatum (crimson clover)**	5	98	85
Eschscholzia californica (California poppy)	3	90	85
Bromus mollis 'Blando' (Blando brome)	5	95	85
Annual Mixture			
Lolium rigidum 'Wimmera 62' (Wimmera 62 ryegrass)	20	97	85
Bromus mollis 'Blando' (Blando brome)	10	95	85
Vicia dasycarpa 'Lana" (Lana woollypod vetch)	10	99	85
Rapid Cover			
Hordeum vulgare (barley)	180	97	80
Bromus mollis 'Blando' (Blando brome)	20	95	85
Vicia dasycarpa 'Lana' (Lana woollypod vetch)	20	99	85
or			
Lolium rigidum 'Wimmera 62' (Wimmera 62 ryegrass)	60	97	85
Bromus mollis 'Blando' (Blando brome)	20	95	85
Vicia dasycarpa 'Lana' (Land woollypod vetch	20	99	85

* Luna has not been adequately tested in MLRA-4.
** Inoculate all legume seed.
Fertilizer recommendations: Ammonium phosphate sulphate 16-20-0 preferred at 400 pounds/acre; or ammonium sulphate 21-0-0 at 300 pounds/acre.

Note: To convert pounds/acre to kg/ha, multiply by 1.091.

MLRA-14. CENTRAL CALIFORNIA COASTAL VALLEYS
MLRA-15. CENTRAL CALIFORNIA COAST RANGE
MLRA-16. CALIFORNIA DELTA
MLRA-17. SACRAMENTO AND SAN JOAQUIN VALLEYS
MLRA-18. SIERRA NEVADA FOOTHILLS

These major Land Resource Areas cover a wide region with a mild Mediterranean-type climate in central and northern California (including the lands fronting along the Pacific Ocean), the coastal, inland and Sierra Nevada Foothills up to 5,000 feet in the south, the coastal and inland mountainous areas, valleys subjected to sea breezes, and the hotter and sometimes drier Sacramento and San Joaquin Valleys. Rainfall is highly variable, ranging from 5 inches near Bakersfield to about 35 inches near timbered areas. Mediterranean annual grasses, forbs, and legumes dominate grassy areas. These areas are combined because several of the better species for erosion control can be commonly used throughout.

	Seeding Rate (pounds/acre)	Minimum Purity (percent)	Germination (percent)
Perennial Mixture. Mean annual precipitation 16"+ (40 cm) (fill slopes or cut slopes with deep soils)			
Agropyron intermedium trichophorum, 'Luna' (pubescent wheatgrass)	25	95	80
Dactylis glomerata 'Berber' (Berber orchardgrass)	10	75	80
Trifolium hirtum (rose clover)**	5	88	85
Optional			
Trifolium incarnatium (crimson clover)**	5	98	85
Eschscholzia californica (California poppy)	3	90	85
Bromus mollis 'Blando' (Blando brome)	5	95	85
Annual Mixture. Mean annual precipitation 12" (30cm) plus			
1. Near Coast			
Bromus mollis 'Blando' (Blando brome)	25	95	85
Lolium rigidum 'Wimmera 62' (Wimmera 62)	10	97	85
Vicia dasycarpa 'Lana' (Lana woollypod vetch)	10	99	85
or			
Bromus mollis 'Blando' (Blando brome)	30	95	85
Trifolium hirtum (rose clover)**	10	99	85
Optional			
Eschscholzia californica (California poppy)	3	90	85
Trifolium incarnatum (Crimson clover)	5	98	85
2. Inland			
Bromus mollis 'Blando' (Blando brome)	25	95	85
Lolium rigidum 'Wimmera 62' (Wimmera 62)	10	97	85
Vulpia myuros 'Zorro' (Zorro annual fescue)	5	90	80

Annual Mixture. (Cont'd)	Seeding Rate (pounds/acre)	Minimum Purity (percent)	Minimum Germination (percent)
Vicia dasycarpa 'Lana' (Lana woollypod vetch)*	10	99	85
or			
Bromus mollis 'Blando' (Blando brome)	30	95	85
Trifolium hirtum (rose clover)**	10	99	85
Optional			
Trifolium incarnatum (crimson clover)**	5	98	85
Eschscholzia californica (California poppy)	3	90	85
Annual Mixture. Mean annual precipitation 6-12" (15-30 cm)			
Bromus mollis 'Blando' (Blando brome)	25	95	85
Trifolium hirtum (rose clover)**	10	99	85
Vulpia myuros 'Zorro' (Zorro annual fescue)	5	90	80
Rapid Cover. Mean annual precipitation 12"+ (30 cm)			
Hordeum vulgare (barley)	180	97	80
Bromus mollis 'Blando' (Blando brome)	20	95	85
Vicia dasycarpa ('Lana' woollypod vetch)+	20	99	85
or			
Lolium rigidum 'Wimmera 62' (Wimmera 62 ryegrass)	60	97	85
Bromus mollis 'Blando' (BLando brome)	20	95	85
Vicia dasycarpa 'Lana' (Lana woolypod vetch)+	20	99	85
Rapid Cover. Mean annual precipitation 10-12" (25-30 cm)			
Hordeum vulgare (barley)	180	97	80
Bromus mollis 'Blando' (Blando brome)	20	95	85
Trifolium hirtum (rose clover)+			
or			
Lolium rigidum ('Wimmera' 62 ryegrass)	50	97	85
Bromus mollis 'Blando' (Blando brome)	20	95	85
Trifolium hirtum (rose clover)+	10	99	85
Vulpia myuros 'Zorro' (Zorro annual fescue)	5	90	80

** Inoculate all legume seed.
Fertilizer recommendation: Ammonium phosphate sulphate preferred

	Ammonium Phosphate Sulphate 16-20-0 (Pounds/Acre)	Ammonium Sulphate 21-0-0 (Pounds/Acre)
Mean annual rainfall 16"+ (40 cm)	400	300
Mean annual rainfall 10-16" (25-40 cm)	300	230
Mean annual rainfall 10"- (25 cm)	200	150

Note: To convert pounds/acre to kg/ha, multiply by 1.091.

MLRA-19. SOUTHERN CALIFORNIA COASTAL PLAIN

This area includes plains, low hills, valleys, and low mountains along the coast from Santa Barbara south to Mexico. From Los Angeles, the area extends inland to San Bernardino and Hemet surrounding the Santa Ana Mountains, which are in MLRA-20. Rainfall varies from 10 to 20 inches (25.4 - 50.8 cm) along the coast. Elevations range from sea level to 2000 feet. Sandy soils in the vicinity of Cucamonga are subject to wind erosion. The erosion hazard is low on alluvial soils but high on steep upland slopes.

	Seeding Rate (pounds/acre)	Minimum Purity (percent)	Minimum Germination (percent)
Perennial Mixture. Coastal influence (deep, light sandy soils*)			
Ehrharta calycina 'Mission' (Mission veldtgrass)	20	64	75
Agropyron intermedium trichophorum** 'Luna' (pubescent wheatgrass)	10	95	80
Trifolium hirtum (rose clover)#	10	99	85
Optional			
Eschscholzia californica (California poppy)	3	90	85
Bromus mollis 'Blando' (Blando brome)	5	95	85
Perennial Mixture. Mean mixture precipitation 16"+ (40 cm) (fill slopes or cut slopes with deep soils)			
Agropyron intermedium trichophorum** 'Luna' (pubescent wheatgrass)	30	95	80
Dactylis glomerata** 'Berber' (Berber orchardgrass)	5	85	80
Trifolium hirtum (rose clover)#	5	99	85
Optional			
Eschscholzia californica (California poppy)	3	90	85
Bromus mollis 'Blando' (Blando brome)	5	95	85
Annual Mixture. Mean annual precipitation 12"+ (30 cm)			
Bromus mollis 'Blando' (Blando brome)	25	95	85
Lolium rigidum 'Wimmera 62' (Wimmers 62 ryegrass)	10	97	85
Vicia dasycarpa 'Lana' (Lana woollypod vetch)	10	99	85
Annual Mixture. Mean annual precipitation 10-12" (25-30 cm)			
Bromus mollis 'Blando' (Blando brome)	30	95	85
Trifolium hirtum (rose clover)#	10	99	85
Optional			
Eschscholzia californica (Californica poppy)	3	90	85
Vulpia myuros 'Zorro' (Zorro annual fesuce)	5	90	80
Rapid Cover. Mean annual precipitation 12"+ (30 cm)			
Hordeum vulgare (barley)	180	97	80
Bromus mollis 'Blando' (Blando brome)	20	95	85
Vicia dasycarpa 'Lana' (Lana woollypod vetch)#	20	99	85

	Seeding Rate (pounds/acre)	Minimum Purity (percent)	Germination (percent)
Rapid Cover. Mean annual precipitation 10-12" (25-30 cm)			
Hordeum vulgare (barley)	180	97	80
Bromus mollis 'Blando' (Blando brome)	20	95	85
Trifolium hirtum (rose clover)#	10	99	85

* Soils highly erosive; slopes should probably be straw mulched.
** 'Luna' and 'Berber' have not been adequately tested in MLRA-19.
\# Inoculate all legume seed.
Fertilizer recommendations: Ammonium phosphate sulphate preferred.

	Ammonium Phosphate Sulphate 16-20-0 (Pounds/Acre)	Ammonium Sulphate 21-0-0 (Pounds/Acre)
Mean annual rainfall 16"+ (40 cm)	400	300
Mean annual rainfall 10-16" (25-40 cm)	300	230
Mean annual rainfall 10"- (25 cm)	200	150

Note: To convert pounds/acre to kg/ha, multiply by 1.091.

MLRA-20. SOUTHERN CALIFORNIA MOUNTAINS

This area extends from the southern part of San Luis Obispo County through several mountain ranges to the Mexican border. The Santa Ana Mountains in Orange County are also included. Fifty-five percent of the area is made up of vast brushfields with steep slopes, 22% is grassy, 10% is oak woodland, and at higher elevations 3% is timbered. The elevations range from about 2,000 feet to nearly 12,000 feet. Precipitation is generally 16-30 inches (40-76 cm) with as much as 40 inches in small forested areas at higher elevations.

	Seeding Rate (pounds/acre)	Minimum Purity (percent)	Germination (percent)
Perennial Mixture. Mean annual precipitation 16"+ (40 cm)			
1. Above 3,500' elevation--coast side of mountains			
Agropyron intermedium trichophorum 'Luna' (pubescent wheatgrass)	20	95	80
Agropyron intermedium 'Greenar' (Greenar intermediate wheatgrass)	10	95	85
Poa ampla 'Sherman' (Sherman big bluegrass)	10	90	70
Bromus mollis 'Blando' (Blando brome)	5	95	85
2. Above 3,000' elevation--desert side of mountains			
Agropyron intermedium trichophorum 'Luna' (pubescent wheatgrass)	20	95	80
Agropyron cristatum 'Ephraim' (crested wheatgrass)	10	95	80
Poa ampla 'Sherman' (Sherman big bluegrass)	10	90	70
3. Below 3,500' elevation--coast side of mountains			
Agropyron intermedium trichophorum 'Luna' (pubescent wheatgrass)	20	95	80
Dactylis glomerata 'Berber' (Berber orchardgrass)	10	85	80
Oryzopsis miliacea (smilo)	10	99	70
Bromus mollis 'Blando' (Blando brome)	5	95	85
Annual Mixture. Below 3,500' elevation			
Bromus mollis 'Blando' (Blando brome)	25	95	85
Lolium rigidum 'Wimmera 62' (Wimmera 62 ryegrass)	10	97	85
Vicia dasycarpa 'Lana' (Lana woollypod vetch)**	10	99	85
or			
Bromus mollis 'Blando' (Blando brome)	30	95	85
Trifolium hirtum (rose clover)**	10	99	85
Eschscholzia californica (California poppy)	3	90	85
Vulpia myuros 'Zorro' (Zorro annual fescue)	5	90	80

	Seeding Rate (pounds/acre)	Minimum Purity (percent)	Germination (percent)
1. Above 3,500' elevation			
Secale cereale (cereal rye)	120	97	80
2. Below 3,500' elevation			
Secale cereale (cereal rye)	120	97	80
or			
Lolium rigidum 'Wimmera 62' (Wimmers 62 ryegrass)	60	97	85
Bromus mollis 'Blando' (Blando brome)	20	95	85
Vicia dasycarpa 'Lana' (Lana woollypod vetch)**	20	99	85

** Inoculate all legume seed.

Fertilizer recommendations: Ammonium phosphate sulphate preferred

	Ammonium Phosphate Sulphate 16-20-0 (Pounds/Acre)	Ammonium Sulphate 21-0-0 (Pounds/Acre)
Mean annual rainfall 16"+ (40 cm)	400	300
Mean annual rainfall 10-16" (25-40 cm)	300	230
Mean annual rainfall 10"- (25 cm)	250	150

Note: To convert pounds/acre to kg/ha, multiply by 1.091.

MLRA-21. KLAMATH AND SHASTA VALLEYS AND BASINS

This area, in the north central and northeastern part of California, is characterized by upland lava mesas interspersed with mountain valleys and lake basins. Elevations range from about 2,500 to 4,500 feet. Precipitation ranges from 10 to 33 inches (25-84 cm). Generally, it is too meager to support stands of forest trees. The dominant woody vegetation is juniper, sagebrush, bitterbrush, and mountain mahogany with scattered Jeffrey pine trees. The drought-tolerant wheatgrasses, such as crested and 'Luna' pubescent, are well adapted.

Perennial Mixture	Seeding Rate (pounds/acre)	Minimum Purity (percent)	Minimum Germination (percent)
Agropyron intermedium trichophorum 'Luna' (pubescent wheatgrass)	20	95	80
Agropyron cristatum Fairway (Fairway crested wheatgrass)	10	95	80
Poa ampla 'Sherman' (Sherman big bluegrass)	10	90	70
Festuca longifolia 'Durar'(Durar hard fescue)	5	95	80
or			
Agropyron riparium 'Sodar' (streambank wheatgrass)	15	95	80
Poa ampla 'Sherman' (Sherman big bluegrass)	15	90	70
Festuca ovina 'Covar' (Covar hard fescue)	15	95	80
Rapid Cover			
Secale cereale (cereal rye)	120	97	80

Fertilizer recommendations: Ammonium phosphate sulphate preferred

	Ammonium Phosphate Sulphate 16-20-0 (Pounds/Acre)	Ammonium Sulphate 21-0-0 (Pounds/Acre)
Mean annual rainfall 16"+ (40 cm)	400	300
Mean annual rainfall 10-16" (25-40 cm)	300	230
Mean annual rainfall 10"- (25 cm)	250	150

Note: To convert pounds/acre to kg/ha, multiply by 1.091.

MLRA-5. SISKIYOU-TRINITY AREA
MLRA-22. SIERRA NEVADA MOUNTAINS

These areas lie in the mountains and mountain valleys at general elevations of 1,300 to over 8,000 feet. Precipitation ranges from 30 to 84 inches (76-213 cm) in MLRA-5, and from 26 to over 100 inches (76-213 cm) in MLRA-22.

Generally, the winters are cold with snow, but at lower elevations the cold climate merges with the Mediterranean climate and wide belts exist where high and low elevation species intermingle. Most of the mountain slopes are forested.

Mediterranean Climate	Seeding Rate (pounds/acre)	Minimum Purity (percent)	Minimum Germination (percent)
Agropyron intermedium trichophorum 'Luna' (pubescent wheatgrass)	25	95	80
Dactylis glomerata 'Berber' (Berber orchardgrass)	10	85	80
Trifolium hirtum (rose clover)**	5	98	85
Optional			
Trifolium incarnatum (crimson clover)**	5	98	85
Eschscholzia californica (California poppy)	3	90	85
Bromus mollis 'Blando' brome)	10	95	85
or			
Agropyron intermedium trichophorum 'Luna' (pubescent wheatgrass)	10	95	80
Agropyron intermedium 'Tegmar' or 'Oahe' (Tegmar or Oahe intermediate wheatgrass)	10	95	85
Poa ampla 'Sherman' (Sherman Big Bluegrass)	5	90	70
Dactylis glomerata 'Latar' or 'Potomac' (Latar or Potomac orchardgrass)	5	98	85
Bromus inermis 'Manchar' (Manchar smooth brome	5	98	85
Astragulus cicer* (cicer milkvetch)**	5	99	85
or for a shorter stand			
Agropyron riparium 'Sodar' (Sodar streambank wheatgrass)	15	90	80
Festuca longifolia 'Durar' (Durar hard fescue)	10	95	85
Astragulus cicer* (cicer milkvetch)**	5	99	85
Annual Mixture			
Bromus mollis 'Blando' (Blando brome)	25	95	85
Lolium rigidum 'Wimmera 62' (Wimmera 62 ryegrass)	10	97	85
Vicia dasycarpa 'Lana' (Lana woollypod vetch)**	10	99	85
or			
Bromus mollis 'Blando' (Blando brome)	30	95	85
Trifolium hirtum (rose clover)**	10	99	85
Optional			
Eschscholzia californica (California poppy)	3	90	85
Vulpia myuros 'Zorro' (Zorro annual fescue)	5	90	80
Trifolium incarnatum (Crimson clover)	5	98	85

Rapid Cover	Seeding Rate (pounds/acre)	Minimum Purity (percent)	Minimum Germination (percent)
Hordeum vulgare (barley)	180	97	80
Bromus mollis 'Blando' (BLando brome)	20	95	85
Vicia dasycarpa 'Lana' (Lana woollypod vetch)	20	99	85
or			
Lolium rigidum 'Wimmera 62' (Wimmera 62 ryegrass)	40	97	80
Bromus mollis 'Blando' (Blando brome)	20	95	85
Vicia dasycarpa 'Lana' (Lana woollypod vetch)	20	99	85
East Side of Sierra on Drier Sites			
Agropyron intermedium trichophorum 'Luna' (pubescent wheatgrass)	20	95	80
Agropyron cristatum Fairway (Fairway crested wheatgrass)	10	95	80
Poa ampla 'Sherman' (Sherman big bluegrass)	10	90	70

** Inoculate all legume seed.
Fertilizer recommendations: Ammonium phosphate sulphate 16-20-0 preferred at 400 pounds/acre, or ammonium sulphate 21-0-0 at 300 pounds/acre.
Tahoe Basin, use 250 pounds/acre ammonium phosphate sulphate 16-20-0 or 200 pounds/acre ammonium sulphate 21-0-0.

Note: To convert pounds/acre to kg/ha, multiply by 1.091.

MLRA-29. SOUTHERN NEVADA BASIN AND RANGE

This area includes most of Inyo County west of Bishop, excluding Death Valley, and extends into Mono and San Bernardino counties. Elevations range from 2,000 to 5,000 feet in valleys to over 13,000 feet in mountainous areas. Mean annual precipitation ranges from 5 inches (13 cm) at lower elevations to 15 inches (38 cm) in the mountains.

	Seeding Rate (pounds/acre)	Purity (percent)	Minimum Germination (percent)
Perennial Mixture. Mean annual precipitation 10"- (25 cm)			
Oryzopsis hymenoides* (Indian ricegrass)	20	90	11-40
Agropyron cristatum* Fairway (Fairway crested wheatgrass)	10	95	80
Rapid cover. Mean annual precipitation 10"+ (25 cm)			
Secale cereale (cereal rye)	120	97	80
Shrubs			
Atriplex canescens 'Marana' (fourwing saltbush)	5		
Atriplex polycarpa (desert saltbush)	5		
Eriogonum fasciculatum (California buckwheat)	5		

* Not adequately tested in MLRA-29.

Inoculate all legume seed.
Fertilizer recommendations: Ammonium phosphate sulphate preferred

	Ammonium Phosphate Sulphate 16-20-0 (Pounds/Acre)	Ammonium Sulphate 21-0-0 (Pounds/Acre)
Mean annual rainfall 10-15" (25-38 cm)	300	230
Mean annual rainfall 10"- (25 cm)	200	150

Note: Because of low and erratic precipitation and dry air, plant establishment and growth are difficult. To enhance establishment of grasses and native shrubs stockpile the top 2-4 inches (5-10 cm) of soil from construction areas and respread on disturbed soils. Run over with tracklayer tractor or a sheepsfoot roller, or if strawed, with a straw puncher, to make a good bond between the topsoil and the underlying material. Punch straw into soil with a straw puncher.

Note: To convert pounds/acre to ka/acre, multiply by 1.091.

MLRA-30. SONORAN BASIN AND RANGE

This desert area includes most of southern Nevada, southwestern Arizona, and southeastern California from Death Valley to the Mexican border. Elevations range from 282 feet below sea level to over 5,000 feet above sea level. Rainfall usually averages less than 5 inches annually, often occurring in thundershowers. Several years may elapse before enough rainfall occurs in one or a series of years to establish plants. The area is very hot in summer, with below-freezing temperatures on winter nights. No information has been found on previous seedings in this area, mainly because the area is a desert and considered impractical to revegetate.

Perennial Mixture	Seeding Rate (pounds/acre)	Minimum Purity (percent)	Minimum Germination (percent)
Oryzopsis hymenoides (Indian ricegrass)	20	90	11-40
Bromus mollis 'Blando' (Blando brome)	5	95	85
Bromus rubens (Red brome)	10	85	40
Vulpia myuros 'Zorro' (Zorro annual fescue)	5	90	80
Shrub Mixture			
Atriplex canescens 'Marana' (fourwing saltbush)	10		
Atriplex polycarpa (desert saltbush)	15		
Encelia farinosa (desert encelia)	5		
Isomeris arborea 'Dorado' (Dorado bladderpod)	15		
Eriogonum fasciculatum 'Duro' (California buckwheat)	5		

Fertilizer recommendations: Ammonium phosphate sulphate (16-20-0) at 250 pounds/acre (273 kg/ha).

Note: To convert pounds/acre to kg/ha, multiply by 1.091.

APPENDIX C

PHOTOGRAPHS OF PROMISING PLANT SPECIES

Above: **'MARANA' FOURWING SALTBUSH,** Atriplex canescens, is an erect, drought tolerant shrub well adapted to alkaline to slightly acid soils in Central and Southern California. It has been established successfully from seed and container stock in areas with as little as 7 inches (18 cm) annual precipitation.

Above Right: **DORADO' BLADDERPOD,** Isomeris arborea var. globosa, is an erect, drought tolerant shrub native to southeastern California. It is best adapted to well drained, alkaline to slightly acid soils. It has been successfully seeded and established from containers at elevations up to 4,000 feet (1223 meters) and in areas with as little as 7 inches (18 cm) annual precipitation.

Right: **DESERT SALTBUSH,** Atriplex polycarpa, is a drought tolerant shrub native to the southern San Joaquin Valley and southeastern California. It is adapted to a wide range of soils and has had the highest rate of success (from both containers and direct seedings) of all shrubs planted in the Mojave Desert. It has performed well where annual precipitation is as low as 4 inches (10 cm).

Below: **SULPHUR FLOWER BUCKWHEAT,** Eriogonum umbellatum, is a low growing, drought tolerant shrub native to the Sierra Nevada Mountains. It can be propagated from seed or cuttings and has been established successfully on a wide range of soils from near sea level to over 6,000 feet (1835 meters) elevation.

Above: **'LANA' WOOLLYPOD VETCH**, Vicia dasycarpa, is a self-seeding, cool season, annual legume well adapted to the Mediterranean climate zones of California. It grows best in areas where the annual rainfall is at least 14 inches (39 cm).

Above Right: **'LUNA' PUBESCENT WHEATGRASS**, Agropyron intermedium trichophorum, is a cool season, self-seeding, perennial rhizomatous grass. It grows best in areas where the annual precipitation is at least 18 inches (46 cm). Within the Mediterranean climate zone 'Luna' has performed best in deep soils on north exposures.

Below Right: **'BERBER' ORCHARDGRASS**, Dactylis glomerata, is a winter active, drought tolerant, self-seeding perennial bunchgrass adapted to areas with an annual rainfall of at least 18 inches (46 cm). It is one of the best perennial grasses for use in erosion control in the Mediterranean climate zone of California.

Below: **ROSE CLOVER**, Trifolium hirtum, is a winter growing, annual legume. It is adapted to well drained, acid to moderately akaline soils in areas that receive 10 inches (25 cm) or more annual precipitation.

Above Left: **'DURAR' HARD FESCUE**, Festuca longifolia, is a short growing, fine textured, cool season, perennial bunchgrass. It grows best in areas of 12 inches (30 cm) or more annual precipitation and is adapted to a wide range of soils in the Sierra Nevada Mountains and Continental climatic zone.

Above Right: **'SHERMAN' BIG BLUEGRASS**, Poa ampla, is an early growing, cool season, bunchgrass. It is best adapted to deep soils within the Sierra Nevada Mountains and the Continental climates where precipitation exceeds 10 inches (25 cm).

Left: **'CASA' QUAILBUSH**, Atriplex lentiformis, is an erect, spreading, drought tolerant shrub adapted to alkaline to slightly acid soils in Central and Southern California below 2,000 feet (611 meters) elevation. It has been established successfully in areas with as little as 7 inches (18 cm) annual precipitation.

Below: **'TEGMAR' INTERMEDIATE WHEATGRASS**, Agropyron intermedium, is a short growing, cool season, self-seeding, perennial sod forming grass. It is highly rhizomatous and best adapted to the Sierra Nevada Mountains and areas in the Continental climate zone where the annual precipitation is at least 14 inches (36 cm).

Above: **'WIMMERA 62' RYEGRASS**, Lolium rigidum, is a winter growing, self-seeding annual grass adapted to areas where the annual rainfall is above 10 inches (25 cm). This species is self-perpetuating whereas common ryegrass tends to persist for only a few years.

Left: **BLANDO' BROME**, Bromus mollis, is an improved strain of soft chess. It is a winter growing, self-seeding, annual grass adapted primarily to areas where the annual rainfall is above 10 inches (25 cm). It is an excellent erosion control species on good soils.

Below Left: **'ZORRO' ANNUAL FESCUE**, Vulpia myuros, is a winter growing, self-seeding annual grass adapted to areas where the annual rainfall is above 10 inches (25 cm). It has provided excellent erosion control cover on soils having a pH as low as 4.5.

Below Right: **RED BROME**, Bromus rubens, is a low-growing, winter active, self-seeding annual grass adapted to areas where the annual rainfall is above 7 inches (18 cm). Stands of red brome have been successfully established in the Mojave Desert as well as in the Mediterranean climate zone.

APPENDIX D

LIST OF COMMON NAMES

Common Name	Variety	Botanical Name
Alfalfa	Rambler	Medicago sativa
Alkali sacaton		Sporabolus airoides
Armed Senna		Cassia armata
Aspen, quaking		Populus tremuloides
Apache plume		Fallugia paradoxa
Arabian grass		Schismus arabicus
Barley		Hordeum vulgare
Bitterbrush, antelope		Purshia tridentata
Bluegrass, annual		Poa annua
Bluegrass, big	Sherman	Poa ampla
Bluegrass, Canada		Poa compressa
Bluegrass, Kentucky		Poa pratensis
Blackbrush		Coleogyne ramosissima
Bladderpod		Isomeris arborea
Bladder sage		Salazaria mexicana
Bladdersenna, common		Colutia arborescens
Brittlebrush		Encelia farinosa
Brome, California	Cucamonga	Bromus carinatus
Brome, cheatgrass		Bromus tectorum
Brome, red		Bromus rubens
Brome, ripgut		Bromus rigidus
Brome, smooth	Manchar	Bromus inermis
Bromus, soft chess	Blando	Bromus mollis
Broomsage, California		Lepidospartum squamatum
Buckeye, California		Aesculus californica
Buckthorn, California or coffeeberry		Rhamnus californica
Buckthorn, redberry		Rhamnus crocea
Buckwheat, California		Eriogonum fasciculatum
Buckwheat, sulphur flower		Erigonum umbellatum
Buffaloberry, Canadian		Shepherdia canadensis
Buffaloberry, Silvery		Shepherdia argentia
Bush encelia		Encelia frutescens
Burrobrush, white		Hymenoclea salsola
Bursage, white		Ambrosia dumosa
Bush senecio		Senecio douglassi
Cactus		Cactus sp.
Cassia		Cassia corymbosa
Catclaw		Acacia greggi
Ceanothus, buckbrush or wedgeleaf		Ceanothus cuneatus
Ceanothus, deerbrush		Ceanothus integerrimus
Ceanothus cuneatus x prostratus hybrid		Ceanothus cuneatus x C.prostratus
Ceanothus, Monterey		Ceanothus rigidus albidus
Ceanothus, mountain whitehorn or snowbush		Ceanothus cordulatus
Ceanothus, Roderick		Ceanothus roderickii
Ceanothus, Santa Barbara		Ceanothus impressus

LIST OF COMMON NAMES (Continued)

Common Name	Variety	Botanical Name
Ceanothus, squaw carpet		Ceanothus prostratus
Ceanothus, tobacco brush or snowbrush		Ceanothus velutinus
Ceanothus, wartleaf		Ceanothus papillosus
Cedar, incense		Libocedrus decurrens
Chaffbush		Amphipappus fremonti
Chamise		Adenostema fasciculatum
Chaparral pea		Pickeringia montana
Cherry, bitter		Prunus emarginata
Cliffrose		Cowania mexicana stansburiana
Clover, crimson		Trifolium incarnatum
Clover, rose	Hykon	Trifolium hirtum
Coffeeberry or California buckthorn		Rhamnus californica
Cooper goldenbush		Haplopappus cooperi
Coyote brush or coyote bush		Baccharis pilularis consanguinea
Coyote brush, prostrate or dwarf	Twin Peaks	Baccharis pilularis
Creosote bush		Larrea tridentata
Crownvetch	Chemung	Coronilla varia
Current		Ribes sp.
Current, Sierra		Ribes nevadensis
Cypress, Arizona		Cupressus arizonica
Cypress, Mcnab		Cupressus macnabiana
Cypress, Saharan		Cupressus depreziana
Cypress, Sargent		Cupressus sargentii
Deer Vetch		Lotus scoparius
Desert alyssum		Lepidiium fremontii
Desert aster		Xylorhiza tortifolia
Desert broom		Baccharis sarothroides
Desert encelia		Encelia farinosa
Dogwood, red osier		Cornus stolonifera
Elderberry, blue		Sambucus caerulea
Encelia, California		Encelia californica
Ephedra, green or Mormon tea		Ephedra viridis
Ephedra, Nevada		Ephedra nevadensis
Fescue, California		Festuca californica
Fescue, foxtail or annual	Zorro	Vulpia myuros
Fescue, hard	Durar	Festuca longifolia
Fescue, hard	Covar	Festuca ovina
Fescue, tall	Soliman	Festuca arundicacea
Fescue, tall	Goar	Festuca arundicacea
Fir, California red		Abies magnifica
Fir, white		Abies concolor
Fir, Douglas		Pseudotsuga menziesii
Flannel bush, California or fremontia		Fremontodendron californicum
Flannel bush, dwarf or fremontia		Fremontodendron decumbens
Four o'clock		Mirabilis bigelovii
Fremont Dalea		Dalea fremontia

Common Name	Variety	Botanical Name
Globemallow		Sphaeralcea ambigua
Goatnut, jojoba		Simmondsia chinensis
Golden fleece		Haplopappus arborescens
Goldenhead		Acamptopappus sphaerochephalus
Gooseberry, Sierra		Ribes roezlii
Guayule		Parthenium argentatum
Greasewood		Sarcobatus vermiculatus
Hairgrass		Aira caryophylla
Hardinggrass		Phalaris tuberosa stenoptera
Harford melic		Melica harfordii
Horsebrush, littleleaf		Tetradymia glabrata
Horsebrush, longspine		Tetradymia axillaris
Hopsage, spiny		Grayia spinosa
Indian wheat		Plantago insularis
June berry		Amelanchier pallida
Koleagrass	Perla	Phalaris tuberosa hirtiglumis
Lilac, common		Syringa vulgaris
Lovegrass, Atherstone		Eragrostis lehmanniana x E. Trichophora
Lovegrass, Lehmann		Eragrotis lehmanniana
Lupine		Lupinus, sp.
Madrone, Pacific		Arbutus menziesii
Manzanita, bearberry or kinnikinnick		Arctostaphylos uva-ursi
Manzanita, bigberry		Arctostaphylos glauca puberula
Manzanita, common		Arctostaphylos manzanita
Manzanita, greenleaf		Arctostaphylos patula
Manzanita, serpentine		Arctostaphylos obispoensis
Manzanita, whiteleaf		Arctostaphylos viscida
Milkvetch, cicer	Lutana	Astragalus cicer
Mojave aster		Aster abatus
Mojave buckwheat		Eriogonum heermannii ssp. humilius
Mojave brickellbush		Brickellia oblongifolia
Monkey flower, northern bush		Mimulus aurantiacus
Mountain mahogany, birchleaf		Cercocarpus betuloides
Mountain mahogany, curlleaf or desert		Cercocarpus ledifolius
Mountain misery or bearmat		Chamaebatia foliolosa
Narrowleaf goldenbush		Haplopappus linearifolius
Oak, blue		Quercus douglassii
Oak, California black		Quercus kelloggii
Oak, California white or valley white		Quercus lobata
Oak, interior		Quercus wislizenii
Oak, leather		Quercus durata
Oak, Sadler		Quercus sadleriana

LIST OF COMMON NAMES (Continued)

Common Name	Variety	Botanical Name
Oak, scrub		Quercus dumosa
Oats, wild		Avena fatua
Oleander		Nerium oleander
Olive, Russian		Elaeagnus angustifolia
Orchardgrass	Berber	Dactylis glomerata
Orchardgrass	Latar	Dactylis glomerata
Orchardgrass	Palestine	Dactylis glomerata
Orchardgrass	Potomac	Dactylis glomerata
Paloverde		Cercidium floridum
Pea shrub, Siberian		Caragana arborescens
Peach, desert or Nevada wild almond		Prunus andersonii
Penstemon, mountain pride		Penstemon newberryi
Penstemon, Rocky Mountain	Bandera	Penstemon strictus
Phlox		Phlox sp.
Pine, Coulter or bigcone		Pinus coulteri
Pine, digger		Pinus sabiniana
Pine, Jeffrey		Pinus jeffreyi
Pine, knobcone		Pinus attenuata
Pine, lodgepole		Pinus murrayana
Pine, Monterey		Pinus radiata
Pine, pinyon		Pinus edulis
Pine, Ponderosa or yellow		Pinus ponderosa
Pine, singleleaf or one-leaved		Pinus monophylla
Pine, sugar		Pinus lambertiana
Pluchea		Pluchea sericea
Poison oak		Rhus diversiloba
Poppy, California		Eschscholzia californica
Poppy, Matilija		Romneya coulteri
Pyracantha	Mojave	Pyracantha koidzumii x P. coccinea
Pyracantha		Pyracantha sp.
Quakinggrass, big		Briza maxima
Rabbitbrush, Desert		Chrysothamnus paniculatus
Rabbitbrush, needleleaf		Chrysothamnus teretifolius
Rabbitbrush, rubber		Chrysothamnus nauseosus
Rayless goldenhead		Acamptopappus sphaerocephalus
Redberry buckthorn		Rhamnus crocea
Redbud, California or western		Cercis occidentalis
Ricegrass, Indian		Oryzopsis hymenoides
Ricegrass, smilo		Oryzopsis miliacea
Rockrose		Cistus villosus
Rose		Rosa, sp.
Rosemary		Rosemarinus officinalis
Ryegrass, annual		Lolium multiflorum
Ryegrass, perennial	Arika	Lolium perenne
Ryegrass, wimmera	Wimmera 62	Lolium rigidum
Sage, black		Salvia mellifera

LIST OF COMMON NAMES (Continued)

Common Name	Variety	Botanical Name
Sage, creeping		Salvia sonomensis
Sage, Dorrs		Salvia dorri
Sagebrush, big		Artemisia tridentata
Sagebrush, Caucasian		Artemisia caucasica
Sagebrush, fringed		Artemisia frigida
Sagebrush, oldman wormwood		Artemisia abrotanum
Sagebrush, prairie		Artemisia ludoviciana
Sagebrush, sand		Artemisia filifolia
Sagebrush, silver		Artemisia cana
Saltbush, Australian		Atriplex semibaccata
Saltbush, desert, allscale or cattle		Atriplex polycarpa
Saltbush, desert holly		Atriplex hymenelytra
Saltbush, fourwing	Marana	Atriplex canescens
Saltbush, fourwing	Wytana	Atriplex canescens
Saltbrush, Gardner		Atriplex gardneri
Saltbush, Muellers		Atriplex muelleri
Saltbush, Nuttall		Atriplex nuttallii
Saltbush, oldman		Atriplex nummularia
Saltbush, quailbush	Casa	Atriplex lentiformis
Saltbush, shadscale		Atriplex confertifolia
Saltbush, spinescale		Atriplex spinifera
Saltbush, Torrey		Atriplex torreyi
Senna, armed		Cassia armata
Senna		Cassia sp.
Serviceberry		Amelanchier pallida
Schotts pigmy cedar		Peucephyllum schottici
Shockley goldenhead		Acamptopappus shockleyi
Silktassel		Garrya elliptica
Smilo		Oryzopsis miliacea
Snakeweed		Gutierrezia lucida
Snowberry		Symphoricarpos vaccinoides
Snowberry whortleaf		Symphoricarpos sp.
Spiny mendora		Mendora spinescens
Squirreltail		Sitanion hystrix
Sweetbush		Bebbia juncea
Sweet clover, yellow blossom		Melilotus officinalis
Sumac squawbush or skunkbush		Rhus trilobata
Sunflower family		Compositae
Summer cypress, green molly		Kochia americana
Summer cypress, prostrate		Kochia prostrata
Thamnosa		Thamnosa montana
Thistle, yellow star		Centaurea solstitialis
Thistle, Russian		Salsola kali var. tenuifolia
Trefoil, birdsfoot	Cascade	Lotus corniculatus
Trefoil, native		Lotus sp.
Tree of Heaven		Ailanthus altissima
Toyon		Heteromeles arbutifolia

LIST OF COMMON NAMES (Continued)

Common Name	Variety	Botanical Name
Tumbleweed, perennial		Salsola vermiculata
Virgin River encelia		Encelia virginensis
Vetch, woollypod	Lana	Vicia dasycarpa
Wheatgrass, fairway crested	Fairway	Agropyron cristatum
Wheatgrass, standard crested		Agropyron desertorum
Wheatgrass, intermediate	Greenar	Agropyron intermedium
Wheatgrass, intermediate	Oahe	Agropyron intermedium
Wheatgrass, intermediate	Tegmar	Agropyron intermedium
Wheatgrass, pubescent	Luna	Agropyron intermedium trichophorum
Wheatgrass, pubescent	Topar	Agropyron intermedium trichophorum
Wheatgrass, Siberian		Agropyron sibiricum
Wheatgrass, slender	Primar	Agropyron trachycaulum
Wheatgrass, streambank	Sodar	Agropyron riparium
Wheatgrass, tall	Largo	Agropyron elongatum
Wheatgrass, thickspike	Critana	Agropyron dasystachyum
Wheatgrass, western	Arriba	Agropyron smithii
Wheatgrass, western	Barton	Agropyron smithii
Wheatgrass, western	Rosana	Agropyron smithii
Wheatgrass, western	727	Agropyron smithii
Wildrye, blue		Elymus glaucus
Willow, dwarf arctic		Salix purpurea nana
Willow, slender arctic		Salix purpurea gracilis
Winterfat		Ceratoides lanata
Wiregrass		Stephanomeria pauciplora
Wolfberry, Anderson or desert thorn		Lycium andersonii
Wolfberry, Cooper or Cooper desert thorn		Lycium cooperi
Woolly brickellbush		Brickellia incana
Yellow bluestem		Andropogon ischaemum
Yerba santa, California		Eriodictyon californicum
Yucca, Joshua		Yucca brevifolia
Yucca		Yucca elata

APPENDIX E

SUPPORTING DATA

TABLES

Table E-1. Location, exposure and soil material at 13 planting sites in California

Location	Exposure*	Soil Material
State Highway 14 and Avenue L	N(f), S(f), F	Coarse sandy loam
State Highway 14 and Avenue G	N(f), S(f), F	Coarse sandy loam
Antelope Valley RCD Nursery	F	Greenfield sandy loam
Edwards Air Force Base	F	Sandy loam
U.S. 395 P.M. 18.8 Kern near Ridgecrest	W(c)	Cobbly sandy loam
I-40 P.M. 41.5 SBD, 40 mi. E. of Barstow near Lavic Road	N(c)	Gravely cobbly sands
State Highway 49, PM 25.0 Cal, near San Andreas	E(c)	Loose to rocky serpentine
State Highway 124, PM 6.75 Ama, 6 mi. N. of Ione	E(c)	Loose to rocky serpentine
I-80, American Canyon, approx. 6 mi. N. of Vallejo	W(c)	Soft to moderately hard sandstone with layers of lignite
State Highway 16, approx. 1 mi. E. of Sacramento-Amador County line	N(c)	Poorly cemented sands and clays
U.S. Borax, Boron	F	Clayey sand
U.S. 395 P.M. 3.3 Mono, 16 mi. N. of Bishop	F	Volcanic tuff
U.S. 395 P.M. 5.5 Inyo, 5 mi. S. of Little Lake	E(c)	Coarse sandy loam, decomposed granite

* N - north facing; S - south facing; W - west facing; E - east facing; (f) - fill flope; (c) - cut slope; F - flat

Table E-2. Species seeded and treatments applied to serpentine soils on Highway 49 near San Andreas

	Treatments 1979-81		Treatments 1979		
	Broadcast Seeding before Mulch	Seed Included in Mulch	Plots Fertilized and Mulched 4,000 lbs/ac	Plots Fertilized and Mulched 2,000 lbs/ac	Plots Fertilized No Seed, No Mulch
'Blando' Brome	x	x			
'Zorro' annual fescue	x	x			
Red brome	x	x			
Quaking grass	x	x			
'Wimmera 62' ryegrass	x	x			
'Marana' fourwing saltbush	x	x			
'Casa' quailbush	x	x			
'Goar' tall fescue	x				
'Berber' orchardgrass	x				
Mueller's saltbush	x	x			
'Dorado' bladderpod	x	x			
California buckwheat	x	x			
'Largo' tall wheatgrass	x				
'Luna' pubescent-wheatgrass	x				
Rose clover	x				
Indigenous vegetation			x	x	x

Table E-2. Species seeded and treatments applied to serpentine soils on Highway 49 near San Andreas

	Treatments 1981									
	Topsoil 1"			Topsoil 3"			Lime			
	16-20-0	Mag Amp	No Fert	16-20-0	Mag Amp	No Fert	16-20-0	Mag Amp	No Fert	Success
'Blando' Brome	x	x	x	x	x	x	x	x	x	1
'Zorro' annual fescue	x	x	x	x	x	x	x	x	x	3
Red brome	x	x	x	x	x	x	x	x	x	2
Quaking grass	x	x	x	x	x	x	x	x	x	2
'Wimmera 62' ryegrass										3
'Marana' fourwing-saltbush										6
'Casa' quailbush										6
'Goar' tall-fescue										8
'Berber' orchardgrass	x	x	x	x	x	x	x	x	x	8
Mueller's saltbush	x	x	x	x	x	x	x	x	x	6
'Dorado' bladderpod										6
California buckwheat										5
'Largo tall wheatgrass										8
'Luna' pubescent wheatgrass										8
Rose clover										7
Indigenous vegetation										7

1 - Earliest growing 1st year, no growth 2nd year, no germination 3rd year
2 - Poor growth 1st year, no growth 2nd year, no germination 3rd year
3 - Good germination and growth but later than 'Blando', no growth 2nd year, no germination 3rd year
4 - Same as 3; residue effective 3+ years
5 - No germination 1st year, plants 1-3" high 2nd year
6 - No germination
7 - Growth good 1st year, similar to #3
8 - Fair growth

Table E-3. Woody species seeded at four problem soil sites in California

Species	Year Planted				Remarks
	San Andreas	Ione	Bishop	Little Lake	
Acacia greggi LK-1193			79,80	79,80	No growth
Ambrosia dumosa LK-1123			78		No growth
Ambrosia dumosa LK-1195			79,80	79,80	No growth
Arbutus menziesii LK-1499	81				No growth
Arctostaphylos glauca var. puberula PL-454-64	81				No growth
Arctostaphylos manzanita LK-1497	81				No growth
Arctostaphylos obispoensis LK-781	81				No growth
Arctostaphylos viscida LK-562	81				No growth
Artemisia tridentata LK-1306			79,80	79,80	Fair-good growth
Artemisia tridentata LK-1067			79,80		No growth
Atriplex canescens 'Marana'	79	80	78,79,80	79,80	Fair-good growth
Atriplex confertifolia LK-1066			78		No growth
Atriplex confertifolia LK-1311			79,80	79,80	No growth
Atriplex lentiformis 'Casa'	79	80	78,79,80	79,80	Fair growth at Little Lake
Atriplex muelleri LK-415	79		79,80	79,80	No growth
Atriplex polycarpa LK-1069			78		No growth
Atriplex polycarpa LK-1169			79,80	79,80	Good growth at Little Lake
Atriplex polycarpa CF&G	81				No growth
Atriplex spinifera LK-1309			79,80	79,80	No growth
Atriplex spinifera LK-1168			78		No growth
Baccharis sarothroides LK-1071			78		No growth
Baccharis sarothroides LK-1307			79,80	79,80	No growth
Ceanothus cuneatus PL-84-71	81				No growth
Ceanothus papillosus PL-31-71	81				No growth
Ceanothus roderickii LK-456	81				No growth
Cercidium floridum LK-1194			79,80	79,80	No growth
Cercidium floridum LK-1122			78		No growth
Cercis occidentalis LK-857	81				No growth
Chrysothamnus nauseosus LK-1065			79,80		No growth
Cistus villosus PL-312-63	81				No growth

Table E-3. Woody species seeded at four problem soil sites in California

Species	Year Planted: San Andreas	Ione	Bishop	Little Lake	Remarks
Cupressus arizonica PL-74-68	81				No growth
Cupressus dupreziana PL-104-70	81				No growth
Cupressus macnabiana LK-1566	81				No growth
Cupressus sargentii LK-1570	81				No growth
Dendromecon rigida LK-391	81				No growth
Elaeagnus angustifolia PL-252-70	81				No growth
Encelia farinosa LK-1070			78		No growth
Encelia farinosa LK-1310			79,80	79,80	Fair-good growth at Little Lake
Eriodictyon californicum LK-156	81				No growth
Eriodictyon californicum, Lake County	81				No growth
Eriogonum fasciculatum T-19947	79	80	78,79,80	78,80	Good growth at San Andreas and Little Lake
Garrya elliptica PL-216-71	81				No growth
Haplopappus linearifolius LK-1196			80	79,80	No growth
Heteromeles arbutifolia, Knoxville	81				No growth
Heteromeles arbutifolia, San Andreas	81				No growth
Isomeris arborea 'Dorado'	79	80	78,79,80	79,80	Poor growth at Little Lake
Larrea tridentata LK-1308			79,80	79,80	No growth
Larrea tridentata LK-1124			78		No growth
Mimulus auranticus PL-131-71	81				No growth
Pinus attenuata, Lake County	81				No growth
Pinus sabiniana, Amador County	81				No growth
Pyracantha sp., Lockeford	81				No growth
Quercus durata LK-1498	81				No growth
Rhamnus californica LK-757	81				No growth
Rhamnus californica LK-1500	81				No growth
Salvia mellifera PL-465-64	81				No growth
Salvia sonomensis LK-812	81				No growth

Table E-4. Herbaceous species seeded at six problem soil sites in California

Species	Year Planted						Remarks
	San Andreas	Ione	I-80	Hwy.16	Bishop	Little Lake	
Agropyron cristatum					78		Fair growth at Bishop
Agropyron dasystachyum, 'Critana'					79,80	79,80	No growth
Agropyron elongatum, 'Largo'	81	80			78-81	79,80	No growth
Agropyron intermedium trichophorum 'Luna'	81	80			79-81	79-80	Fair growth at Bishop
Agropyron sibiricum LK-1295					79-80	79,80	No growth
Agropyron smithii 'Arriba'					79-80	79,80	No growth
Agropyron smithii 'Barton'					79-80	79,80	No growth
Agropyron smithii 'Rosana'					79,80	79,80	No growth
Agropyron smithii LK-1296					79,80	79,80	No growth
Agropyron smithii LK-1298					79,80	79,80	No growth
Andropogon ischaemum P-15626					79,80	79,80	No growth
Bromus mollis 'Blando'	79	80	80,81	80,81	78,81	79,80	Fair growth in 1st year at all locations
Bromus rubens PL-103-71	79	80			78,81	79,80	" only annual to persist
Briza maxima	79						Poor growth
Dactylis glomerata, 'Berber'	79	80	80,81	80,81	78,80	79,80	Excellent growth on State Hwy.16; Fair on I-80
Dactylis glomerata, 'Palestine'		80			78-80	79,80	No growth
Eragrostis lehmanniana, A-68					78,80	79,80	No growth
Eragrostis lehmanniana x E. trichophora PI-276033					79,80	79,80	No growth

Table E-4. Herbaceous species seeded at six problem soil sites in California (Cont'd)

Species	Year Planted: San Andreas	Ione	I-80	State Hwy.16	Bishop	Little Lake	Remarks
Festuca arundinacea, 'Goar'	79	80					No growth
Festuca arundinacea, 'Soliman'		80					No growth
Hordeum vulgare 'Briggs'		80			78		Fair growth during 1st year
Lolium rigidum, 'Wimmera 62'		80			78-81	79,80	"
Oryzopsis hymenoides, 'Paloma'					78-80	79-80	No growth
Oryzopsis miliacea, Smilo		80			78-80	79,80	No growth
Phalaris tuberosa hirtiglumis, 'Perla' koleagrass		80					No growth
Plantago insularis LK-1044					78-80	79,80	No growth
Sporobolus airoides P-14711					78-80	79-80	No growth
Trifolium incarnatum		80					Fair growth during 1st year
Trifolium hirtum, 'Hykon'	81	80					"
Trifolium hirtum, common	79		80,81	80,81			Fair growth during 1st and 2nd year at all locations
Vicia dasycarpa, 'Lana'	79	80					Fair growth in 1st year
Vulpia myuros 'Zorro'	79	80	80,81	80,81	78-81	79-80	Good growth

Table E-5. Species planted as balled stock or from containers at four problem soil sites in California

Species	Year Planted: San Andreas	Bishop	Little Lake	Boron	Remarks
Adenostoma fasciculatum LK-1632	81,82				No survival
Aesculus californica LK-1355	80,82				No survival
Aesculus californica LK-1518	81				No survival
*Agropyron dasystachyum 'Critana'		81	81		No survival
*Agropyron elongatum 'Largo'	81	81	81		Good to excellent survival & growth
*Agropyron intermedium trichophorum 'Luna'	81	81	81		Good survival & growth
Ambrosia dumosa LK-1586		81			Good survival
Arbutus menziesii LK-1519	81				Poor survival
Arbutus menziesii LK-1356	80,81				Poor survival
Arctostaphylos obispoensis LK-1638	81,82				Poor survival
Arctostaphylos obispoensis LK-1633	81				Poor survival
Arctostaphylos viscida LK-1353	80				No survival
Artemisia abrotanum LK-1254		80	80		Poor survival and growth
Artemisia cana LK-1326			79-81	80	Good survival, fair growth
Artemisia frigida EPC-589		81	79,81		Good survival, fair growth
Artemisia ludoviciana LK-1257		81	79,81		Fair survival, poor growth
Artemisia tridentata LK-1171		81	79,81		Good survival & growth at Little Lake & Bishop
Artemisa tridentata LK-1258		80	80		No survival
Atriplex canescens 'Marana'	80,81,82	80,81,82	81,82	80	Good survival & growth at Bishop, Little Lake & Boron Good survival at San Andreas but poor growth

Table E-5. Species planted as balled stock or from containers at four problem soil sites in California (Cont'd)

Species	Year Planted: San Andreas	Bishop	Little Lake	Boron	Remarks
Atriplex canescens LK-1120		80	80		No growth
Atriplex canescens 'Wytana'		81	79,80		Poor growth
Atriplex confertifolia LK-1259		81	80,81	80	Good survival & growth at Little Lake
Atriplex gardneri LK-2183		82	82		Fair survival
Atriplex lentiformis 'Casa'	81,82		79,80,81	80	Good survival & growth at Little Lake
Atriplex nummularia T-6312	81,82	81,82	81,82	80	Excellent growth & survival
Atriplex nuttalli LK-1382			81		No growth
Atriplex polycarpa LK-1169		81,82	81,82	80	Excellent growth & survival at all locations
Atriplex polycarpa LK-1267			79,80		Good growth
Atriplex torreyi LK-1508			81,82		Fair growth
Atriplex torreyi LK-1137			81,82		No growth
Baccharis sarothroides LK-1585		81	81		Good growth; Irrigation may aid growth rates
Baccharis pilularis PL-6-71		81			No survival
Baccharis pilularis LK-912		81			No survival
Cassia corymbosa PI-421039			81	81	No survival
Ceanothus cuneatus T-18125	82				Poor survival
Ceanothus cuneatus T-6338	80				Poor survival
Ceanothus cuneatus T-6340	82				No survival
Ceanothus cuneatus T-1812	82				No survival
Ceanothus cuneatus T-14100	82				No survival
Ceanothus cuneatus T-18126	82				No survival
Ceanothus impressus T-18128	82				No survival
Ceanothus papillosus LK-1634	81				Fair survival

Table E-5. Species planted as balled stock or from containers at four problem soil sites in California (Cont'd)

Species	Year Planted				Remarks
	San Andreas	Bishop	Little Lake	Boron	
Ceanothus rigidus albus T-6534	82				Fair survival
Ceanothus sp. LK-1636	81,82				No growth
Cercidium floridum PL-187-64			79		No growth
Cercis occidentalis LK-1520	81				No growth
Cercis occidentalis LK-1357	80,82				No growth
Chrysothamnus nauseosus LK-1327		80,81	80,81	80	Good growth both locations
Chrysothamnus nauseosus LK-1172			79		Good growth both locations
Chrysothamnus nauseosus LK-1851			82		Good growth both locations
Ceratoides lanata LK-2152		82	82		Fair growth, very palatable
Cercocarpus montanus LK-2180		82			Fair growth
Coleogyne ramosissimum LK-2184		82			No growth
Colutea arborescens LK-1328		80			No growth
Cowania mexicana LK-1329		80	80		No growth
Cupressus macnabiana LK-1566	81				Fair survival, poor growth
Cupressus sargentii LK-1635	81,82				Fair survival, poor growth
Cupressus sargentii LK-1637	81				Fair survival, poor growth
*Dactylis glomerata 'Berber'	81	81	81		Good survival
*Dactylis glomerata 'Palestine'	81	81	81		Poor-fair
*Elymus glaucus	82				
Ephedra nevadensis LK-1384		80-81	81		Good survival, slow growth
Ephreda viridis LK-1385		80-81	81,82		Good survival, slow growth
Eriogonum fasciculatum T-19947	82	81,82	81,82		Good, excellent
Eriogonum fasciculatum LK-1764			79		Fair growth

Table E-5. Species planted as balled stock or from containers at four problem soil sites in California (Cont'd)

Species	Year Planted: San Andreas	Bishop	Little Lake	Boron	Remarks
Fallugia paradoxa LK-2181		82	82		Fair growth
Fallugia paradoxa NM-809		80			Fair growth
*Festuca arundinacea 'Goar'	81				No survival
*Festuca californica LK-1573	81				No survival
Grayia spinosa LK-1982			82		No survival
Grayia spinosa LK-162			81		Fair survival
Heteromeles arbutifolia, LK-1529	81				No survival
Heteromeles arbutifolia, LK-1358	80,82				No survival
Haplopappus cooperi LK-2171			82		No survival
Hymenocloa salsola LK-16766			82		No survival
Isomeris arborea 'Dorado'	81		79,82		Poor growth, both locations
Larrea tridentata LK-1911			82		Fair growth
Larrea tridentata LK-1587		81	81		Fair growth
Lepidium fremontii LK-2158			82		No growth
Lotus scoparius LK-1056	81				No growth
Lycium andersonii T-6581	81	80	79,81,82	80	Fair growth
Lycium andersonii A-17860			81		Fair growth
Lycium cooperi LK-2130			82		No growth
*Melica harfordii LK-1288	81				No growth
*Melica harfordii LK-1290	81				No growth
*Oryzopsis miliacea, Smilo	82	81	81		Excellent growth & survival at San Andreas & Little Lake
*Oryzopsis hymenoides, 'Paloma'		81	81		No growth
Parthenium argentatum T-22182			82		No growth
Pinus edulis LK-2182		82			Fair survival, poor growth

Table E-5. Species planted as balled stock or from containers at four problem soil sites in California (Cont'd)

Species	Year Planted: San Andreas	Bishop	Little Lake	Boron	Remarks
Pinus coulteri LK-1521	81				Fair survival, poor growth
Pinus coulteri LK-1359	80				Fair survival, poor growth
Pinus jeffreyi LK-1522	81				"
Pinus jeffreyi LK-1360	80				"
Pinus monophylla LK-1261	80				"
Pinus ponderosa LK-1527	81				"
Pinus ponderosa LK-1361	80,82				"
Pinus sabiniana LK-1362	80				"
Pinus sabiniana LK-1523	81				"
Pluchea sericea LK-2148			82		No growth
Prunus fasciculata NM940		80	79,81		Fair growth at Bishop
Purshia tridentata LK-1587		81			"
Pyracantha koidzumii x P. coccinea 'Mohave'	82				No growth
Quercus douglassi LK-1524	81,82				No growth
Quercus dumosa LK-1525	81				No growth
Quercus kellogii LK-1526	81,82				No growth
Quercus sadleriana LK-1354	80				No growth
Quercus wislizenii	82				No growth
Rhamnus californica LK-1528	81				No growth
Rhamnus californica LK-1363	80				No growth
Rhamnus crocea T-27646	82				No growth
Rhamnus crocea T-6596	82				Fair-poor survival
Rhus trilobata LK-1754	82				No growth
Rhus trilobata PL-573-64	82				No growth
Rhus trilobata LK-1753	82				No growth
Salazaria mexicana LK-2178		82	82		Fair-poor growth

Table E-5. Species planted as balled stock or from containers at four problem soil sites in California (Cont'd)

Species	Year Planted: San Andreas	Bishop	Little Lake	Boron	Remarks
Shepherdia argentea LK-1263		80,81			No growth
Shepherdia canadensis LK-1383		80,81			No growth
Senecio douglassii LK-1649			82		Fair growth
*Sitanion hystrix	82				No growth
*Sporobolus airoides			81		No growth
*Stipa speciosa		81	81		Fair growth at Little Lake
Umbellularia californica, LK-1364	80				No growth
Xylorhiza tortifolia LK-2168			82		No growth

*Grasses

Table E-6. Woody species seeded at four sites in the Mojave Desert

Species	Year Planted				Remarks
	Lancaster	EAFB	Ridgecrest	Lavic Road	
Acacia greggi LK-1193		79	79,80	79,80	No growth
Acamptopappus shockleyi LK-2136			81	81	No growth
Acamptopappus sphaerocephalus, LK-1662			81	81	No growth
Acamptopappus sphaerocephalus, LK-2172			81	81	No growth
Acamptopappus sphaerocephalus, LK-2128			81		No growth
Ambrosia dumosa LK-1654			81	81	No growth
Ambrosia dumosa LK-1123	78		78		No growth
Ambrosia dumosa LK-2147			81	81	No growth
Ambrosia dumosa LK-1195		79	79,80	79,80	No growth
Ambrosia dumosa LK-2126			81		No growth
Amphipappus fremontii LK-2109			81		No growth
Artemisia tridentata LK-1067	78		78		No growth
Artemisia tridentata LK-1306		79	79,80	79,80	No growth
Aster abatus LK-2176			81	81	No growth
Atriplex canescens LK-2125			81		No growth
Atriplex canescens 'Marana'	78	79	78-80	79,80	Good growth at Ridgecrest & Lavic Road
Atriplex canescens LK-2129			81		No growth
Atriplex confertifolia LK-1066	78		78		No growth
Atriplex confertifolia LK-1131		79	79,80	79,80	No growth
Atriplex confertifolia LK-1659			81	81	No growth
Atriplex lentiformis 'Casa'	78	79	78-80	79,80	Fair growth at Ridgecrest & Lavic Road
Atriplex muelleri LK-415		79	79,80	79,80	No growth
Atriplex polycarpa LK-1069	78	79	78	79	No growth
Atriplex polycarpa LK-1169			79,80	79,80	Excellent growth
Atriplex polycarpa LK-2117			81		No growth
Atriplex spinifera LK-1655			81	81	No growth
Atriplex spinifera LK-1309		79	79,80	79,80	No growth

Table E-6. Woody species seeded at four sites in the Mojave Desert (Cont'd)

Species	Year Planted				Remarks
	Lancaster	EAFB	Ridgecrest	Lavic Road	
Atriplex spinifera LK-1168			78		No growth
Atriplex spinifera LK-2139			81	81	No growth
Atriplex spinifera LK-2143			81	81	No growth
Atriplex spinifera LK-2149			81		No growth
Baccharis sarothroides LK-1071	78		78		No growth
Baccharis sarothroides LK-1307		79	79,80	79,80	No growth
Bebbia juncea LK-1664			81	81	No growth
Bebbia juncea LK-1646			81	81	No growth
Brickellia incana LK-2175			81	81	No growth
Brickellia oblongifolia LK-2150		81		81	No growth
Cassia armata LK-2120		81			No growth
Ceratoides lanata LK-2174			81	81	Germ.at Ridgecrest but no persistence
Ceratoides lanata LK-2152			81	81	No growth
Ceratoides lanata LK-2118			81		No growth
Cercidium floridum LK-1194		79	79,80	79,80	No growth
Cericidum floridum LK-1122	78		78		No growth
Chrysothamnus nauseosus LK-1065	78		78		No growth
Chrysothamnus paniculatus LK-2106			81		No growth
Chrysothamnus teretifolius LK-2108			81		No growth
Dalea fremontia LK-1651			81	81	No growth
Encelia farinosa LK-1310		79	79,80	79,80	Good growth at Ridgecrest
Encelia farinosa LK-1070	78		78		No growth
Encelia farinosa LK-2173			81	81	No growth
Encelia frutescens LK-1647			81	81	No growth
Encelia virginensis LK-2115			81		No growth
Encelia virginensis LK-2145			81		No growth
Ephedra californica LK-1669			81	81	No growth
Ephedra viridis LK-2123			81		Good growth at Ridgecrest
Eriogonum fasciculatum T-19947	78	79	78-80	79,80	No growth
Eriogonum fasciculatum LK-2135			81	81	No growth
Eriogonum fasciculatum LK-2138			81	81	No growth

Table E-6. Woody species seeded at four sites in the Mojave Desert

Species	Year Planted				Remarks
	Lancaster	EAFB	Ridgecrest	Lavic Road	
Acacia greggi LK-1193		79	79,80	79,80	No growth
Acamptopappus shockleyi LK-2136			81	81	No growth
Acamptopappus sphaerocephalus, LK-1662			81	81	No growth
Acamptopappus sphaerocephalus, LK-2172			81	81	No growth
Acamptopappus sphaerocephalus, LK-2128			81		No growth
Ambrosia dumosa LK-1654			81	81	No growth
Ambrosia dumosa LK-1123	78		78		No growth
Ambrosia dumosa LK-2147			81	81	No growth
Ambrosia dumosa LK-1195		79	79,80	79,80	No growth
Ambrosia dumosa LK-2126			81		No growth
Amphipappus fremontii LK-2109			81		No growth
Artemisia tridentata LK-1067	78		78		No growth
Artemisia tridentata LK-1306		79	79,80	79,80	No growth
Aster abatus LK-2176			81	81	No growth
Atriplex canescens LK-2125			81		No growth
Atriplex canescens 'Marana'	78	79	78-80	79,80	Good growth at Ridgecrest & Lavic Road
Atriplex canescens LK-2129			81		No growth
Atriplex confertifolia LK-1066	78		78		No growth
Atriplex confertifolia LK-1131		79	79,80	79,80	No growth
Atriplex confertifolia LK-1659			81	81	No growth
Atriplex lentiformis 'Casa'	78	79	78-80	79,80	Fair growth at Ridgecrest & Lavic Road
Atriplex muelleri LK-415		79	79,80	79,80	No growth
Atriplex polycarpa LK-1069	78	79	78	79	No growth
Atriplex polycarpa LK-1169			79,80	79,80	Excellent growth
Atriplex polycarpa LK-2117			81		No growth
Atriplex spinifera LK-1655			81	81	No growth
Atriplex spinifera LK-1309		79	79,80	79,80	No growth

Table E-6. Woody species seeded at four sites in the Mojave Desert (Cont'd)

Species	Year Planted				Remarks
	Lancaster	EAFB	Ridgecrest	Lavic Road	
Atriplex spinifera LK-1168			78		No growth
Atriplex spinifera LK-2139			81	81	No growth
Atriplex spinifera LK-2143			81	81	No growth
Atriplex spinifera LK-2149			81		No growth
Baccharis sarothroides LK-1071	78		78		No growth
Baccharis sarothroides LK-1307		79	79,80	79,80	No growth
Bebbia juncea LK-1664			81	81	No growth
Bebbia juncea LK-1646			81	81	No growth
Brickellia incana LK-2175			81	81	No growth
Brickellia oblongifolia LK-2150		81		81	No growth
Cassia armata LK-2120		81			No growth
Ceratoides lanata LK-2174			81	81	Germ.at Ridgecrest but no persistence
Ceratoides lanata LK-2152			81	81	No growth
Ceratoides lanata LK-2118			81		No growth
Cercidium floridum LK-1194		79	79,80	79,80	No growth
Cericidum floridum LK-1122	78		78		No growth
Chrysothamnus nauseosus LK-1065	78		78		No growth
Chrysothamnus paniculatus LK-2106			81		No growth
Chrysothamnus teretifolius LK-2108			81		No growth
Dalea fremontia LK-1651			81	81	No growth
Encelia farinosa LK-1310		79	79,80	79,80	Good growth at Ridgecrest
Encelia farinosa LK-1070	78		78		No growth
Encelia farinosa LK-2173			81	81	No growth
Encelia frutescens LK-1647			81	81	No growth
Encelia virginensis LK-2115			81		No growth
Encelia virginensis LK-2145			81		No growth
Ephedra californica LK-1669			81	81	No growth
Ephedra viridis LK-2123			81		Good growth at Ridgecrest
Eriogonum fasciculatum T-19947	78	79	78-80	79,80	No growth
Eriogonum fasciculatum LK-2135			81	81	No growth
Eriogonum fasciculatum LK-2138			81	81	No growth

Table E-6. Woody species seeded at four sites in the Mojave Desert (Cont'd)

Species	Year Planted				Remarks
	Lancaster	EAFB	Ridgecrest	Lavic Road	
Eriogonum fasciculatum LK-2119			81		No growth
Eriogonum heermannii ssp., humilius LK-2142			81	81	No growth
Grayia spinosa LK-1657			81	81	No growth
Haplopappus cooperi LK-2113			81		No growth
Haplopappus cooperi LK-2171			81	81	No growth
Haplopappus linearifolius LK-1196		79	79	79-80	
Haplopappus linearifolius LK-1663			81	81	No growth
Hymenoclea salsola LK-1666			81	81	No growth
Hymenoclea salsola LK-2121			81		No growth
Isomeris arborea 'Dorado'	78	79	78-80	79,80	Fair-poor growth at Ridgecrest
Isomeris arborea LK-1660			81	81	Fair-good growth at Ridgecrest
Isomeris arborea LK-2170			81	81	"
Isomeris arborea LK-2153			81		"
Isomeris arborea LK-2124			81		"
Larrea tridentata LK-2127			81		No growth
Larrea tridentata LK-1308		79	79,80	79,80	No growth
Larrea tridentata LK-1124	78		78		No growth
Lepidium fremontii LK-1658			81	81	No growth
Lepidium fremontii LK-2131			81		No growth
Lycium cooperi LK-1980			81	81	No growth
Menodora spinescens LK-2140			81	81	No growth
Mirabilis bigelovii LK-1652			81	81	No growth
Peucephyllum schottici LK-1645			81	81	No growth
Pluchea sericea LK-2148			81	81	No growth
Prunus andersonii LK-2137			81	81	No growth
Prunus andersonii LK-2116			81		No growth
Psorothamnus fremontii var. fremontii LK-2146			81	81	No growth
Salazaria mexicana LK-1653			81	81	No growth
Salvia dorrii LK-2132			81	81	No growth
Salvia dorrii LK-1667			81	81	No growth

Table E-6. Woody species seeded at four sites in the Mojave Desert (Cont'd)

Species	Year Planted				Remarks
	Lancaster	EAFB	Ridgecrest	Lavic Road	
Salvia dorrii LK-2134			81	81	No growth
Senecio douglassi LK-1661			81	81	No growth
Senecio douglassi LK-1649			81	81	No growth
Sphaeralcea ambigua LK-1656			81	81	No growth
Sphaeralcea ambigua LK-2111			81		No growth
Sphaeralcea ambigua LK-2164			81		No growth
Tetradymia axillaris LK-2144			81	81	No growth
Tetradymia glabrata LK-2133			81	81	No growth
Tetradymia glabrata LK-2107			81		No growth
Tetradymia spinosa LK-2112			81		No growth
Thamnosa montana LK-1665			81	81	No growth
Xylorhiza tortifolia LK-2168			81		No growth
Yucca brevifolia LK-2141			81	81	No growth

Table E-7. Herbaceous species seeded at four sites in the Mojave Desert

Species	Year Planted				Remarks
	Lancaster	EAFB	Ridgecrest	Lavic Road	
Agropyron cristatum			78		No growth
Agropyron dasystachyum 'Critana'		79	79,80	79,80	Germ. 1979; no persist.
Agropyron desertorum LK-692	78		78		"
Agropyron elongatum 'Largo'	78	79	78-81	79,80	"
Agropyron intermedium, trichophorum 'Luna'	78	79	78-81	79,80	"
Agropyron sibiricum, PL-170-70	78		78		No growth
Agropyron sibiricum, LK-1295		79	79,80	79,80	No growth
Agropyron smithii 'Arriba'		79	79,80	79,80	Germ. 1979; no persist.
Agropyron smithii 'Barton'		79	79,80	79,80	"
Agropyron smithii 'Rosana'		79	79,80	79,80	"
Agropyron smithii LK-1296		79	79,80	79,80	"
Agropyron smithii Lk-1298		79	79,80	79,80	"
Andropogon ischaemum P-15626	78	79	78-80	79-80	"
Bromus mollis 'Blando'	78	79	78-81	79,80	Growth in 1st year
Bromus rubens Pl-103-71	78	79	78-81	79,80	Only annual to persist
Dactylis glomerata 'Berber'	78	79	78-80	79,80	Poor germ.in 1979; no persist.
Dactylis glomerata 'Palestine'	78	79	78-80	79,80	"
Eragrostis lehmanniana A-68	78	79	78-80	79,80	"
Eragrostis lehmanniana x E. trichophora PI-276033		79	79,80	79,80	"
Hordeum vulgare 'Briggs'	78				Germ. 1st year
Lolium rigidum 'Wimmera 62'	78	79	78-80	79,80	Good growth 1st year, no persist
Oryzopsis hymenoides 'Paloma'	78	79	78-80	79,80	No growth
Oryzopsis miliacea, Smilo	78	79	78-80	79,80	No growth
Plantago insularis LK-1044	78	79	78-80	79,80	Germ. in 79; no persist.

Table E-7. Herbaceous species seeded at four sites in the Mojave Desert (Cont'd)

Species	Year Planted				Remarks
	Lancaster	EAFB	Ridgecrest	Lavic Road	
Poa compressa 'Rubens'	78				No growth
Sporobolus airoides A-14711	78	79	78-80	79,80	Germ. in 79; no persist.
Trifolium hirtum, common			81		Good germ; should use early maturing variety
Vulpia myuros 'Zorro'	78	79	78-81	79,80	Good growth 1st year; poor persist

Table E-8. Species planted from containers at six sites in the Mojave Desert

Species	Year Planted: Lancaster Ave L	Lancaster Ave G	AVRCD	EAFB	Ridgecrest	Lavic Road	Remarks
Acamptopappus sphaerocephalus LK-2172			82				Good survival
*Agropyron dasystachyum 'Critana'					81		No survival
*Agropyron elongatum 'Largo'					81		Fair survival
*Agropyron intermedium trichophorum, 'Luna'					81		Fair survival
Aloysia sp. LK-1902					82		No survival
Ambrosia dumosa LK-1195				79			No survival
Ambrosia dumosa LK-2147			82		82		Good survival
Ambrosia dumosa LK-1586					81		Good survival
Ambrosia dumosa LK-549		79					Fair survival
Artemisia abrotanum LK-1254			80	79,80	79		No survival
Artemisia cana LK-1326			80	79,80	81	79,81	Fair survival, poor growth
Artemisia cana LK-1016		79					"
Artemisia filifolia LK-1255			80	79,80		81	Poor survival, poor growth
Artemisia filifolia LK-1017		79					"
Artemisia frigida EPC-589			80	79,80	81	80	"
Artemisia frigida LK-1256			80				"
Artemisia ludoviciana LK-1257			80	79,80		79	"
Artemisia tridentata Lk-1258			80	79,80	80	79	Good survival at all locations except Lavic Road
Artemisia tridentata LK-1171			80	79	81	81	"
Artemisia tridentata LK-1012	78	78					Good survival
Artemisia abatus LK-2176				82	82	82	Good survival
Atriplex canescens LK-805	78	78,79					Good survival
Atriplex canescens LK-1173			80	79,80	79	79	Good survival
Atriplex canescens 'Marana'	78	78,79					Good survival
Atriplex canescens 'Wytana'			80	79,80		79	Poor growth
Atriplex canescens LK-1120			80	80			Fair-good growth
Atriplex confertifolia LK-1259			80	79,80	79,80,81	79,81	Good growth; eliminated in 3rd year at Lavic Road

Table E-8. Species planted from containers at six sites in the Mojave Desert (Cont'd)

Species	Year Planted: Lancaster Ave L	Lancaster Ave G	AVRCD	EAFB	Ridgecrest	Lavic Road	Remarks
Atriplex gardneri LK-2183			82		82		Fair-good growth
Atriplex lentiformis 'Casa'	78	78,79	80	79,80	80,81	81	Fair growth; eliminated at EAFB by rabbits
Atriplex nummularia PI-415461		79					Good growth
Atriplex nummularia PI-415858		79					Good growth
Atriplex nummularia T-6312			82		81.82	81.82	Good growth
Atriplex nuttalli LK-1382			80		81	81	Poor growth
Atriplex polycarpa LK-1013	78	78					Fair-good growth
Atriplex polycarpa LK-1267			80	80	80	79	Good growth; eliminated at EAFB by rodents
Atriplex polycarpa LK-1169			80	79,80	79,81,82	82	
Atriplex polycarpa LK-42	78	78,79					Good growth
Atriplex polycarpa LK-320		79					Good growth
Atriplex polycarpa PL-7569		79					Good growth
Atriplex polycarpa LK-316		79					Good growth
Atriplex spinifera LK-1068			80				No growth
Atriplex torreyi LK-1508			82		82	82	Fair-good growth
Atriplex torreyi LK-1137					81		No growth
Baccharis sarothoides LK-1585					81		Good growth
Brickellia incana LK-2175			82				Fair growth
Cassia corymbosa PI-421039			80	79,80	79,81		No growth
Cassia sp. PL-46-72				79			No growth
Ceratoides lanata LK-1117			80				Fair growth
Ceratoides lanata LK-1119			80				Fair growth
Ceratoides lanata LK-1331			80	79			Fair growth; eliminated at EAFB by rodents
Ceratoides lanata LK-2152					82	82	Fair growth
Cercidium floridum PL-187-64			80				No growth

Table E-8. Species planted from containers at six sites in the Mojave Desert (Cont'd)

Species	Year Planted: Lancaster Ave L	Lancaster Ave G	AVRCD	EAFB	Ridgecrest	Lavic Road	Remarks
Cercidium floridum LK-1122			80				No growth
Cercocarpus montanus LK-2180			82				Fair growth
Chrysothamnus nauseosus LK-1327			80	80	80,81	79	Good growth except EAFB
Chrysothamnus nauseosus LK-1172			80	79,80			"
Chrysothamnus nauseosus LK-1979					82	82	"
Chrysothamnus nauseosus LK-1851			82				"
Chrysothamnus nauseosus, LK-1014	78	78,79					"
Chrysothamnus nauseosus, LK-802	78	78					"
Cistus villosus			80				"
Coleogyne ramosissima LK-2184			82				Poor growth
Colutea arborescens LK-1328			80	79,80	79		No growth
Cowania mexicana LK-1329			80	79,80	79		No growth
*Dactylis glomerata 'Berber'					81	81	Poor growth
*Dactylis glomerata 'Palestine'					81	81	Poor growth
Dalea pulchea LK-1907					82		No growth
Dalea spinosa LK-1906					82		No growth
Encelia farinosa LK-1330				79	79		Fair-good growth
Encelia sp. Pl-261-72				79			No growth
Encelia virginensis LK-2160			82				Poor growth
Ephedra californica LK-1669			82		82	82	Fair growth
Ephedra nevadensis LK-1384			80		81		Fair survival; slow growth
Ephedra nevadensis LK-1021	78	78					
Ephedra viridis LK-1385			80		81		"
Ephedra viridis LK-2156			82		82	82	"
Eriogonum fasciculatum, T-19947	78	78	80,82	79	81		Excellent growth except EAFB
Eriogonum fasciculatum LK-1764				80	80,82	82	Good growth except EAFB
Fallugia paradoxa NM-809			80	79			Fair growth at AVRCD

Table E-8. Species planted from containers at six sites in the Mojave Desert (Cont'd)

Species	Year Planted: Lancaster Ave L	Lancaster Ave G	AVRCD	EAFB	Ridgecrest	Lavic Road	Remarks
Fallugia paradoxa LK-2181			82		82	82	Fair growth at AVRCD
Grayia spinosa LK-1982					82		Fair growth
Grayia spinosa LK-162		79			81		Fair growth
Haplopappus cooperi LK-2171					82		No growth
Hymenoclea salsola LK-202			80,82				No growth
Hymenoclea salsola LK-1666					82	82	No growth
Isomeris arborea LK-1660					82	82	Excellent growth
Isomeris arborea 'Dorado'	78	78	80	79			Poor growth
Larrea tridentata LK-1587					81		Good growth
Larrea tridentata LK-1911			82		82	82	Good growth
Lepidium fremontii LK-2158			82		82	82	No growth
Lycium andersonii A-17860					81		Fair growth
Lycium andersonii T-6581	78		80	79,80	81,82	82	Fair growth except at EAFB
Lycium cooperi LK-2130			82		82	82	No growth
*Oryzopsis hymenoides 'Paloma'					81	81	No growth
*Oryzopsis miliacea, Smilo					81	81	Good growth at Ridgecrest
Parthenium argentatum T-22182			82		82	82	Poor growth
Pluchea sericea LK-2148					82	82	Poor growth
Prunus fasciculata NM-940			80	79,80	80,81		Fair growth except EAFB
Purshia tridentata LK-1853			82				Fair growth
Purshia tridentata LK-1262			80				Fair growth
Salazaria mexicana LK-1981					82	82	Fair-poor growth
Salsola vermiculata LK-1185			80		79		Fair-poor growth
Salvia dorrii LK-1667			82		82	82	Fair growth
Senecio douglassii LK-1649			82		82	82	Fair growth
Shepherdia argentea LK-1263			80	79,80	79		Poor growth, eliminated at EAFB
Shepherdia canadensis LK-1383			80				No growth
Sphaeralcea ambigua LK-1656			82		82		Good growth

Table E-8. Species planted from containers at six sites in the Mojave Desert (Cont'd)

Species	Year Planted: Lancaster Ave L Ave G	AVRCD	EAFB	Ridgecrest	Lavic Road	Remarks
*Sporobolus airoides				81	81	No growth
*Stipa speciosa					81	No growth
Tetradymia spinosa LK-276		80				No growth
Thamnosa montana LK-1665				82		No growth
Xylorhiza tortifolia LK-2168				82	82	No growth
Yucca brevifolia LK-2179				82	82	Poor growth
Yucca elata LK-34		80	79,80		79	Poor growth

*Grasses

Table E-9. Locations of sites sampled to determine rate of invasion of woody plants onto highway cut and fill slopes

Type of Slope	Location
	Sierra Nevada Mountains (West)
Cut	State Highway 49, PM NEV 24.4
Cut	Colfax Sewage Treatment Plant Road S. of I-80
Cut	State Highway 88, PM AMA 46.2
Cut	State Highway 88, PM AMA 50.7
Fill	State Highway 88, PM AMA 51.0
Fill	State Highway 88, PM AMA 61.0
Fill	State Highway 88, PM AMA 61.0
Cut	State Highway 88, 1 mile E. of State 88 on Ellis Road
Cut	State Highway 88, 3.6 miles E. of State 88 on Ellis Road
Cut	State Highway 88, 3.6 miles E. of State 88 on Ellis Road
Fill	State Highway 88, 3.6 miles E. of State 88 on Ellis Road
Cut	State Highway 108, PM TUO 11.5, near Twain Hart
Cut	State Highway 108, PM TUO 11.5, near Twain Hart
Fill	State Highway 108, PM TUO 11.5, near Twain Hart
Fill	State Highway 108, PM TUO 11.5, near Twain Hart
	Sierra Nevada Mountains (East)
Cut	3 miles S. of State Highway 89 on county road; near Markleeville
Fill	3 miles S. of State Highway 89 on county road; near Markleeville
Fill	3 miles S. of State Highway 89 on county road; near Markleeville
Fill	2 miles E. of State Highway 4 on Wolf Creek Road; near Markleevile
Cut	1.8 miles E. of State Highway 4 on Wolf Creek Road; near Markleeville
Cut	State Highway 4, PM ALP 27+, 0.4 mile N. of bridge; near Markleeville
Fill	State Highway 89, PM ALP 11.6+, Pistol Range; near Markleeville
Cut	State Highway 89, PM ALP 11.6+, Pistol Range; near Markleeville
Cut	State Highway 89, PM ALP 19.1, near Markleeville
Cut	State Highway 89, PM ALP 19.1, near Markleeville
Fill	State Highway 89, PM ALP 19.1, near Markleeville
Fill	State Highway 89, PM ALP 19.1, near Markleeville
Cut	State Highway 89, PM ALP 18.5, near Markleeville
Cut	State Highway 89, PM ALP 17.9, near Markleeville
Fill	Nevada State Highway 207, PM DO 6.1 (Big Curve) on Kingsbury Grade
Fill	Nevada State Highway 207, PM DO 6.7 on Kingsbury Grade
Cut	Nevada State Highway 207, PM DO 7.2 on Kingsbury Grade
Cut	State Highway 267, 0.3 mile S. on Northstar Drive, near Northstar Development
Cut	State Highway 267, 0.3 mile S. on Northstar Drive, near Northstar Development
Fill	State Highway 267, 0.3 mile S. on Northstar Drive, near Northstar Development
Fill	State Highway 267, Old Landfill on Big Springs Drive, near Northstar Development

Table E-9. Locations of sites sampled to determine rate of invasion of woody plants onto highway cut and fill slopes (Cont'd)

Type of Slope	Location
	Sierra Nevada Mountains (East) (Cont'd)
Cut	State Highway 97, PM SIS 12.75, near Mt. Shasta
Cut	State Highway 97, PM SIS 13.00, near Mt. Shasta
Fill	State Highway 97, PM SIS 16.0, near Mt. Shasta
Fill	State Highway 97, PM SIS 16.0, near Mt. Shasta
	Sierra Nevada Foothills
Cut	Behind Congregation Church Apts, opposite Persimmon Way, Auburn
Cut	State Highway 49, about 0.5 mile N. on Bell Road near Auburn
Cut	State Highway 49, about 0.5 mile N. on Bell Road near Auburn
Cut	Green Valley Road N. of Folsom near Cameron Park
Cut	Green Valley Road N. of Folsom near Cameron Park
Cut	Latrobe Road 0.45 mile S. of South Shingle Road, Amador County
Cut	Latrobe Road 1.3 miles S. of South Shingle Road, Amador County
Fill	Latrobe Road 2.35 miles S. of South Shingle Road, Amador County
Cut	Owens-Illinois, near Ione
Cut	Owens-Illinois, near Ione
Fill	State Highway 124 and Tonzi Road N. of Ione
Fill	State Highway 124 and Tonzi Road N. of Ione
Cut	State Highway 124 PM AMA 9.00
Cut	State Highway 124 PM AMA 9.00
Fill	State Highway 49, PM AMA 9.9 near Amador City
Fill	State Highway 49, PM AMA 9.9 near Amador City
Cut	State Highway 49 PM TUO 27.17
Fill	State Highway 49, PM TUO 27.00^{+}
Cut	State Highway 20, 0.1 mile W. of Pleasant Valley Road near Penn Valley
Cut	State Highway 20, 0.1 mile W. of Pleasant Valley Road near Penn Valley
Cut	Sundew Road, Dunlap, 40 miles E. of Fresno
Cut	Chuckwagon Road, Dunlap, 40 miles E. of Fresno
Cut	State Highway 36, PM TEH 60^{+}, near Red Bluff
Fill	State Highway 36, PM TEH 60^{+}, near Red Bluff
Cut	State Highway 36, PM TEH 62.25, near Red Bluff
Fill	State Highway 4, PM CAL 8.7, near Copperopolis
Fill	State Highway 4, PM CAL 8.7, near Copperopolis
Cut	State Highway 4, Diamond 20 Road, near Copperopolis
	Mojave Desert
Fill	State Highway 14, PM KER 6.12, Dawn Road Overpass near Lancaster
Fill	State Highway 14, PM KER 6.12, Dawn Road Overpass near Lancaster
Fill	State Highway 14, PM KER 9.00, Bacchus Road Overpass near Lancaster

Table E-9. Locations of sites sampled to determine rate of invasion of woody plants onto highway cut and fill slopes (Cont'd)

Type of Slope	Location
	Mojave Desert (Cont'd)
Fill	State Highway 14, PM KER 9.00, Bacchus Road Overpass near Lancaster
Fill	State Highway 14, Avenue J Overpass near Lancaster
Fill	State HIghway 14, PM KER 20,00, Drainage channel near Mojave
Fill	State Highway 14, PM KER 20.00, Drainage channel near Mojave
Cut	State Highway 58, PM KER 123
Cut	State Highway 58, PM KER 123
Fill	State Highway 58, Twenty Mule Team Road Overpass near Boron
Fill	State Highway 58, Twenty Mule Team Road Overpass near Boron
Cut	Interstate 15, PM SBD 97.75, near Barstow
Cut	Interstate 15, PM SBD 97.75, near Barstow
Cut	Interstate 40, PM SBD, Nebo Road Exit, near Barstow
Fill	Interstate 40, PM SBD, Nebo Road Exit, near Barstow
Fill	Interstate 40, PM SBD, Nebo Road Exit, near Barstow
Cut	Interstate 40, PM SBD 42.00, Lavic Road Overpass near Ludlow
Cut	Interstate 40, PM SBD 85
Cut	Interstate 40, PM SBD 85
Cut	State Highway 14, PM KER 37^{+}, near Red Rock Canyon
Cut	State HIghway 14, PM KER 37^{+}, near Red Rock Canyon
Fill	State HIghway 14, PM KER 37^{+}, near Red Rock Canyon
Cut	US 395 and Randsburg Road, near Randsburg
Cut	US 395 and Randsburg Road, near Randsburg
Fill	US 395 and Randsburg Road, near Randsburg
Fill	US 395 and Randsburg Road, near Randsburg
Fill	US 395, PM KER 19.14, near Ridgecrest
Fill	US 395, PM KER 19.14, near Ridgecrest
Cut	US 395, PM KER 19.14, near Ridgecrest
Cut	US 395, PM KER 19.14, near Ridgecrest

Table E-10. Seed cleaning methods and seed treatments for shrubs showing potential for revegetation in the Mojave Desert and vicinity

Species	Seed Cleaning Method	Propagation Techniques and Seed Treatments
Ambrosia dumosa	Hammermill, screen	Seed. Germination improved by stratification in moist sand at 20C for 30 days
Artemisia tridentata*	Hammermill, screen, fan	Seed. No treatment; keep seed moist until germination
Atriplex canescens	Dewing, fan	Seed. No treatment
Atriplex confertifolia	Dewing, fan	Seed. Soaking and drying may improve germination
Atriplex hymenelytra	Fan	Seed. No treatment
Atriplex lentiformis	Fan	Seed. No Treatment
Atriplex polycarpa	Fan	Seed. No Treatment
Atriplex nummularia	Fan	Seed. No treatment
Atriplex torreyi	Fan	Seed. No treatment
Baccharis sarothroides*	Hammermill	Seed. No treatment; keep seed moist until germination
Chrysothamnus nauseosus*	Hammermill	Seeds. No treatment; keep seed moist until germination
Ephedra viridis	Dry	Seed. No treatment
Eriogonum fasciculatum	Hammermill	Seed. No treatment
Encelia farinosa	Hammermill, fan	Seed. No treatment; keep seed moist until germination
Grayia spinosa	Hammermill, screen, fan	Seed. No treatment
Isomeris arborea	Hammermill	Seed. No treatment
Larrea tridentata*	Hammermill	Seed. Soaking and rinsing seed twice in 24 hours may increase germination

*Use fresh seed unless older seed has been kept in cold storage.

Table E-11. Flowering dates, maturity dates and methods of seed collection for shrubs showing potential for revegetation in the Mojave Desert and vicinity

Species	Flowering	Maturity	Methods of Seed Collection
Ambrosia dumosa	Mar-May	May-June	Handstrip; seed is a bur
Artemisia tridentata	Aug-Oct	Oct-Dec	Handstrip into containers
Atriplex canescens*	Jun-Aug	Oct-Dec	Handstrip into containers
Atriplex confertifolia	Jul-Oct	Oct-Dec	Handstrip into containers
Atriplex hymenelytra	Apr-May	Jun-Jul	Handstrip into containers
Atriplex lentiformis	Aug-Oct	Oct-Jan	Handstrip into containers
Atriplex polycarpa	Jul-Oct	Oct-Nov	Handstrip or knock into bags or other containers
Atriplex nummularia**	Aug-Oct	Oct-Nov	Handstrip into containers
Atriplex torreyi	Aug-Oct	Oct-Jan	Handstrip into containers
Baccharis sarothroides	Aug-Sept	Sept-Oct	Handpick or shake into bags
Chrysothamnus nauseosus	Aug-Oct	Oct-Nov	Handpick or shake into bags
Ephedra viridis	Mar-May	May-Jul	Handpick into containers
Erigonum fasciculatum	May-Oct	June-Nov	Handstrip into containers
Encelia farinosa	Jun-July	July-Aug	Handpick or shake into bags
Grayia spinosa	April	April-May	Handstrip into containers
Isomeris arborea	Most of year	Jul-Sept	Handpick into bags
Larrea tridentata	Nov-May	May-Aug	Handpick or shake into bags

* 'Marana' is a released variety of Atriplex canescens
'Casa' is a released variety of Atriplex lentiformis
'Dorado' is a released variety of Isomeris arborea
** Nonnative